Trigger efficiency correction
&
Energy scale correction
&
studies with helium

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Outline

- Trigger efficiency correction study for helium as a function of true energy (both for LE & HE trigger threshold):
  available beam energies: 13, 19, 150 GeV/n

- Energy scale correction study for helium as a function of true energy (both for LE & HE trigger threshold):
  available beam energies: 13, 19, 150 GeV/n

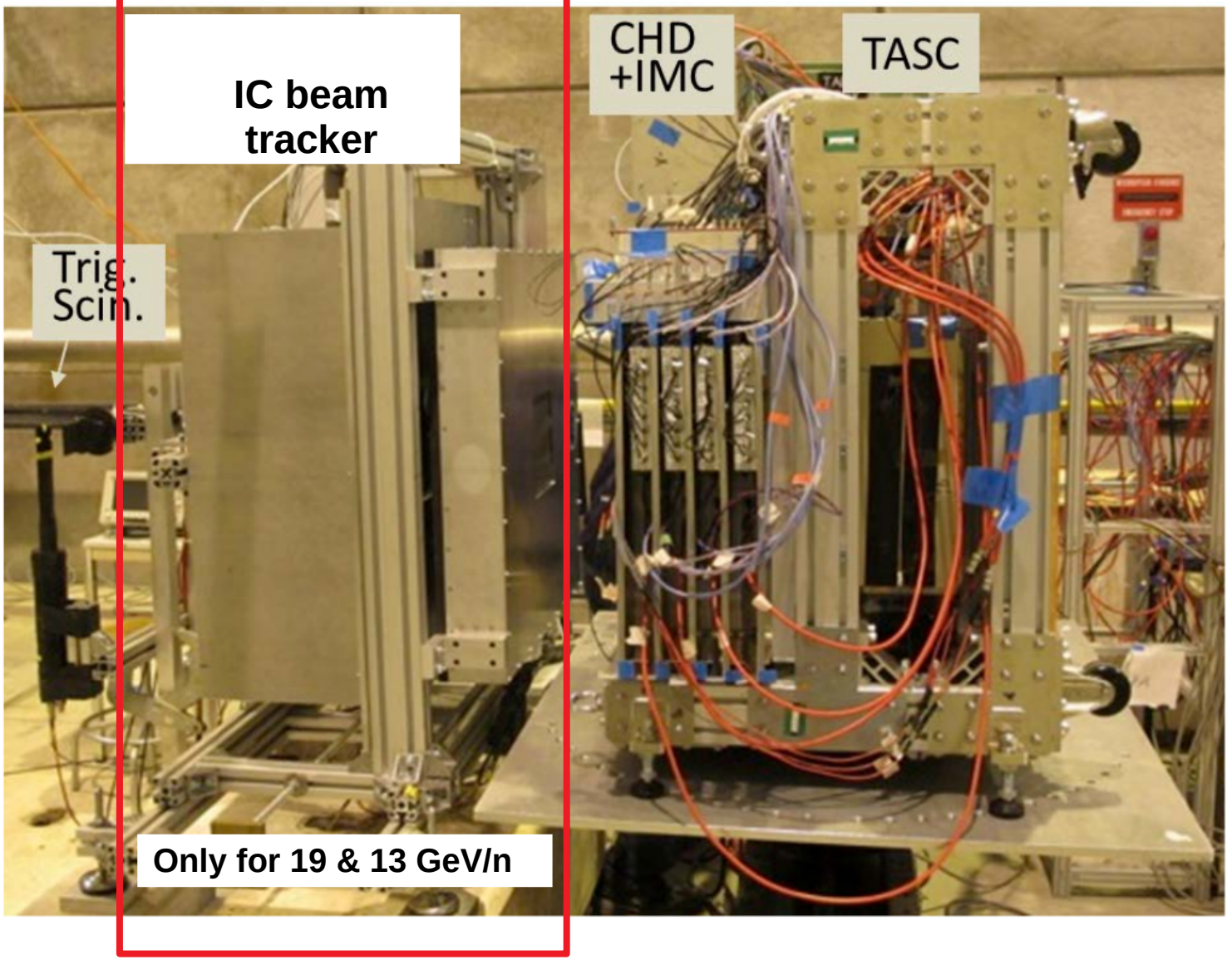
- Data from 2015 Beam Test @ CERN SPS

- TASC calibration & MC digitization with Helium nuclei

- **Comparison between BT data and MC simulations (both Fluka & Epics):**
  100k events sample for BT and MC
  BT physics trigger selected using IC beam tracker trigger flag
  Z charge preselection using the signals from the Trigger Scintillators
  (only for 150 GeV/n beam energy, IC beam tracker was not installed in front of CALET)
  Z charge preselection using IC beam tracker matrices (only for 13 & 19 GeV/n beam energy)
  CHD Z charge selection applied both to BT and MC data

- **Conclusions**

Beam Test Setup (from BT 2012)



Event Display

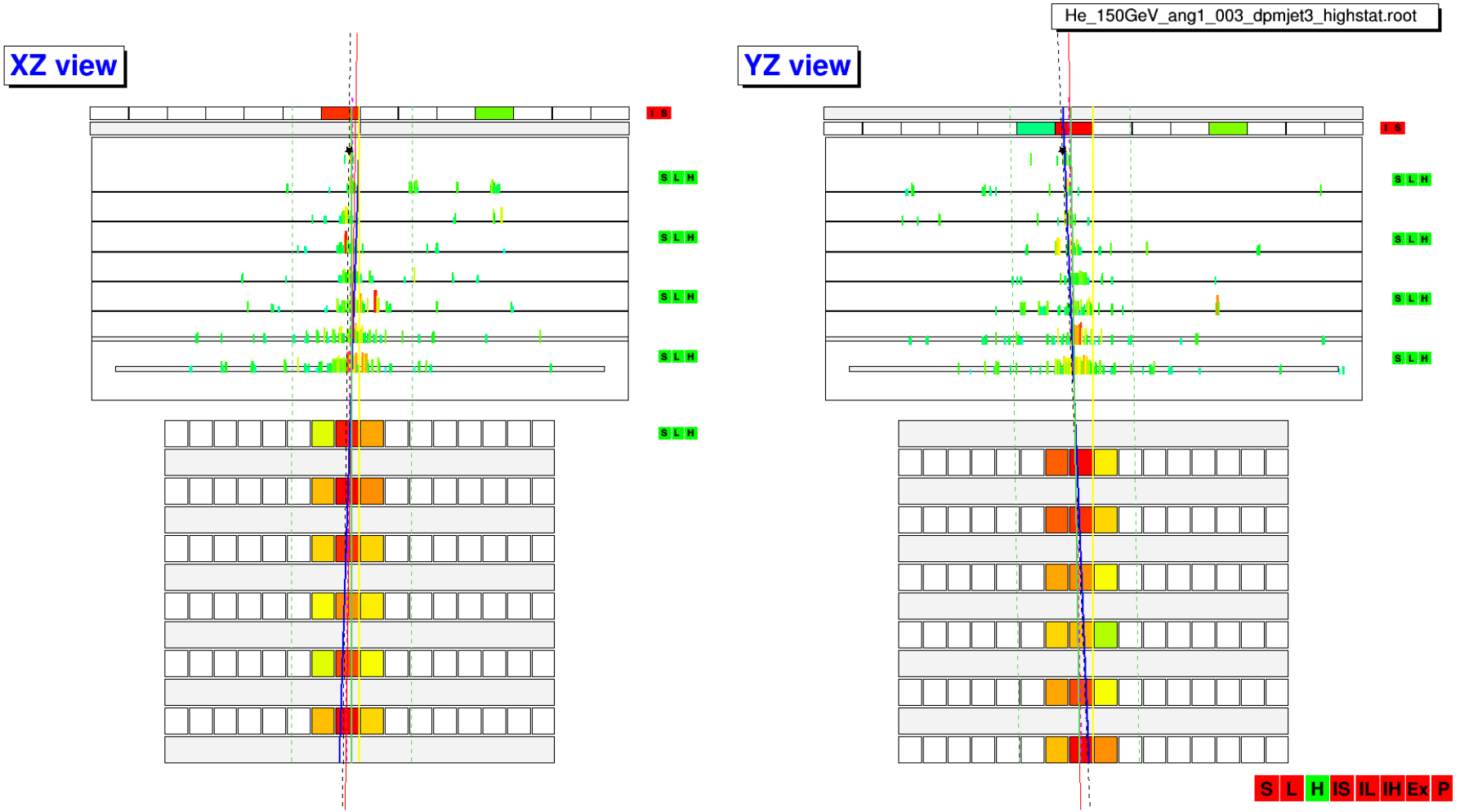
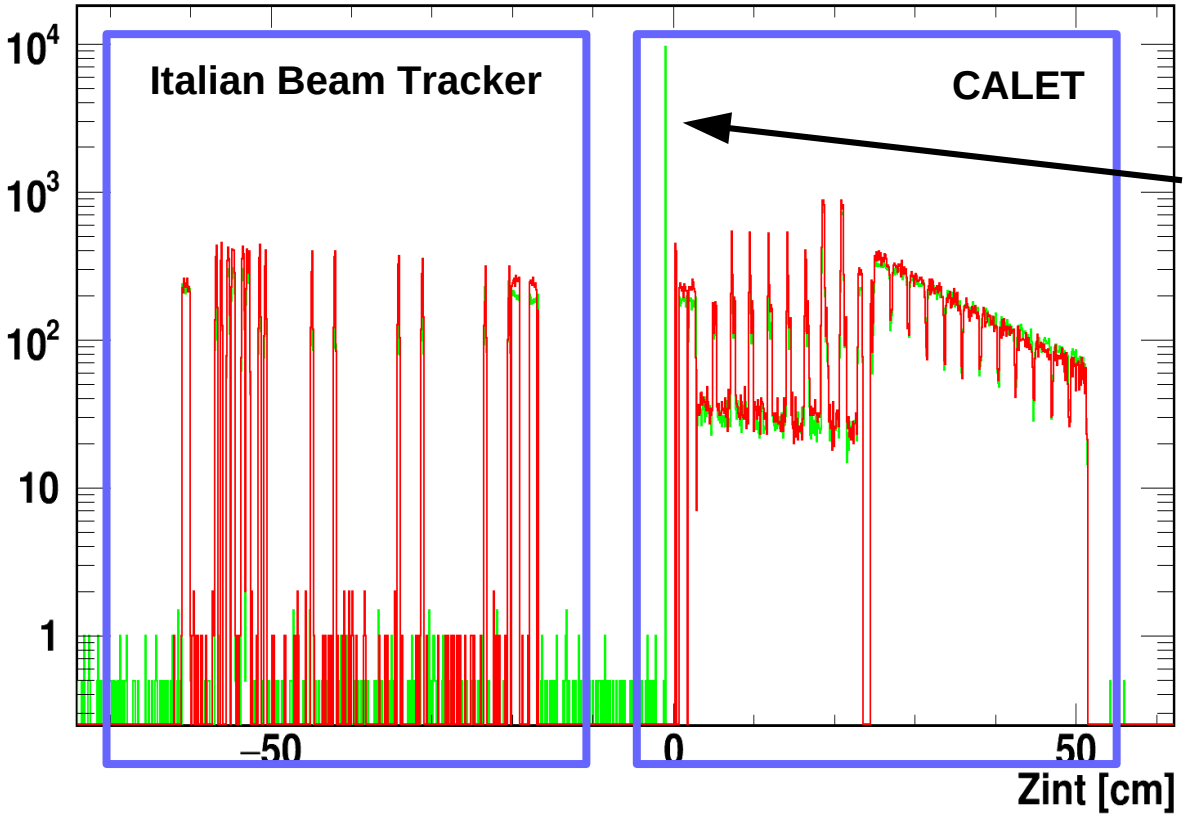


Image of a 150 GeV/n Helium event. During the 2015 Beam Test at CERN-SPS, only three scintillators for each layer of CHD and three logs (except TASC-X1 & TASC-Y1 including 9 layers) for each layer of TASC were instrumented.

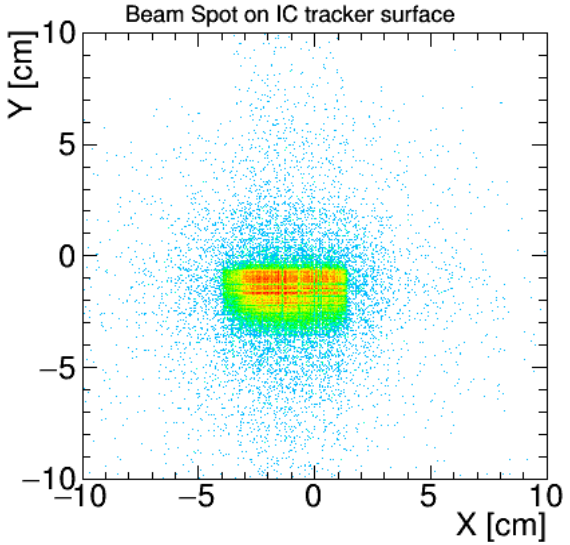
Comparison between longitudinal interaction point (Zint): Fluka (blue plot) vs Epics (green Plot)
(from a 19 GeV/n helium sample)

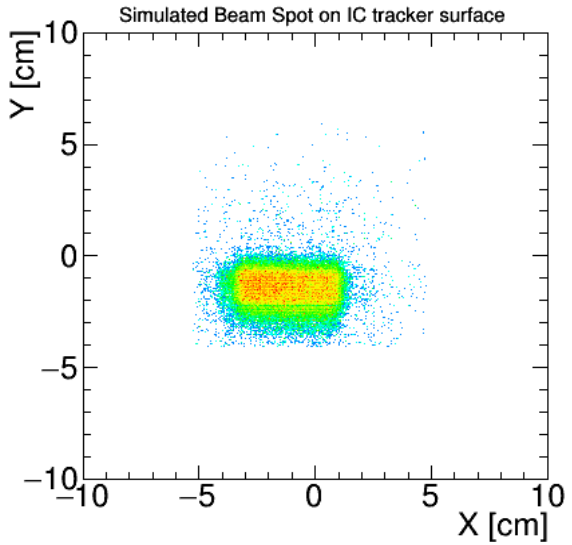


Strange spike in front of CALET in Epics simulation

Red plot: Fluka simulation
Green plot: EPICS simulation (many thanks to Akaike-san for his support)

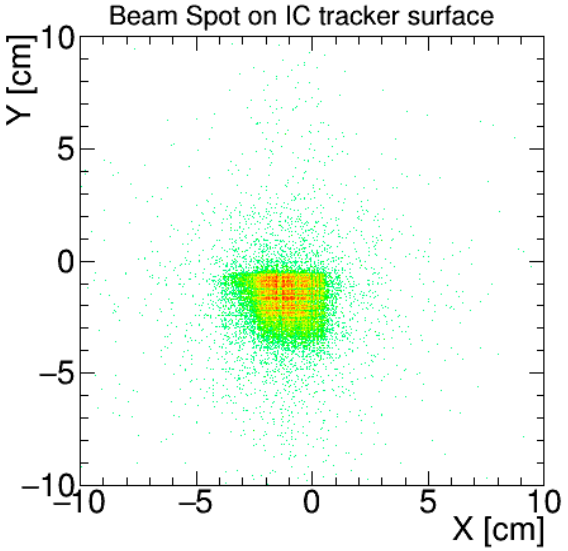
Beam position selection (19 +13 GeV/n)

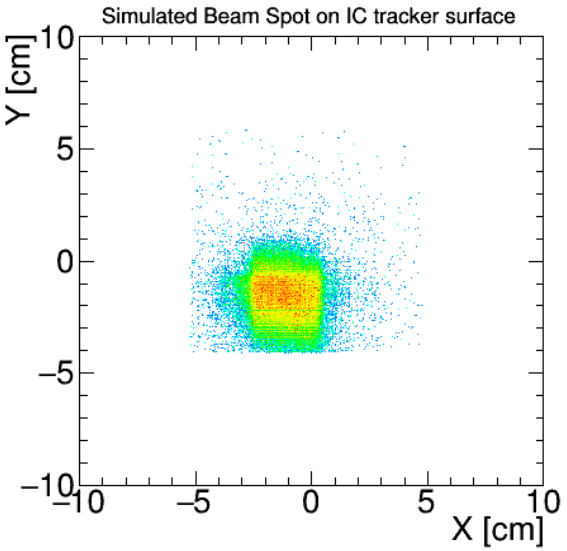




19 GeV/n helium

In principle, in both cases (13+19 GeV/n), the beam position can be selected using IC tracker (BT 2015 data) or MC truth (MC simulation)

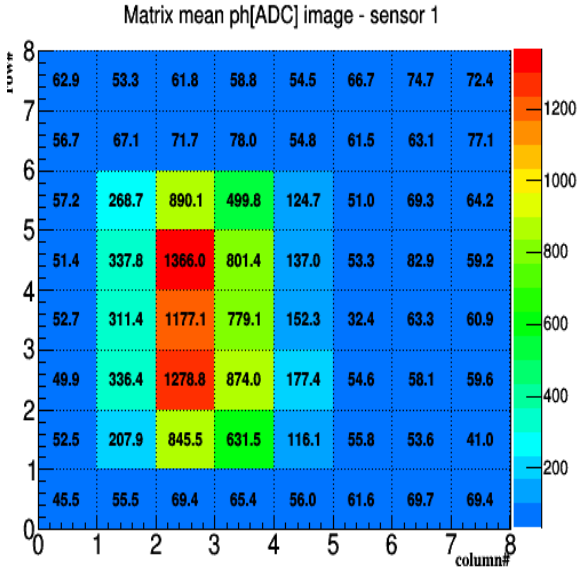


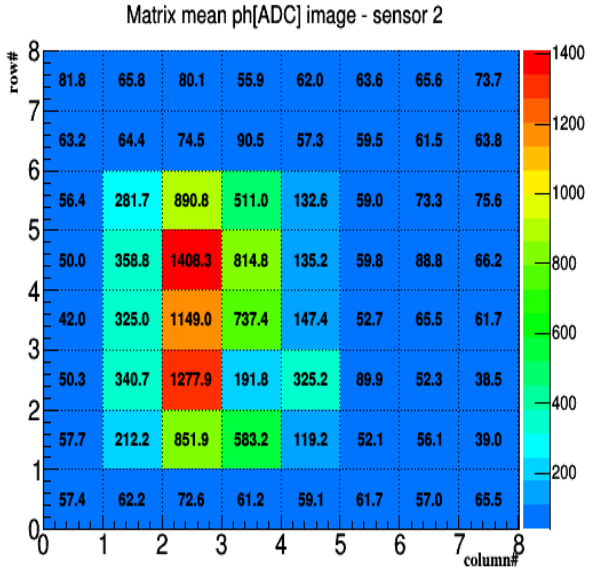


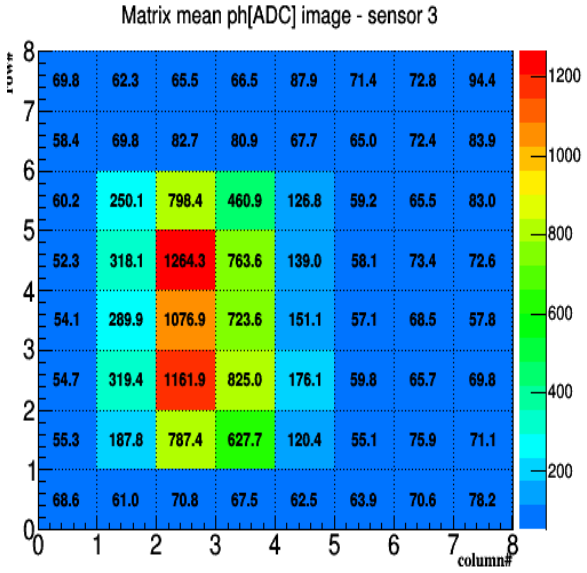
13 GeV/n helium

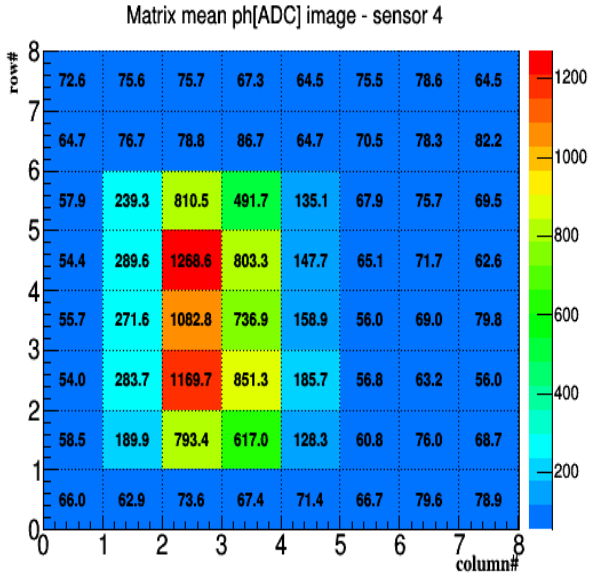
Z Charge pre-selection: 13 GeV/n & 19 GeV/n TB data

The idea is to built a position cut and a charge estimator avoiding the information from reconstructed tracks by IC tracker or IMC (minimum biased cuts)





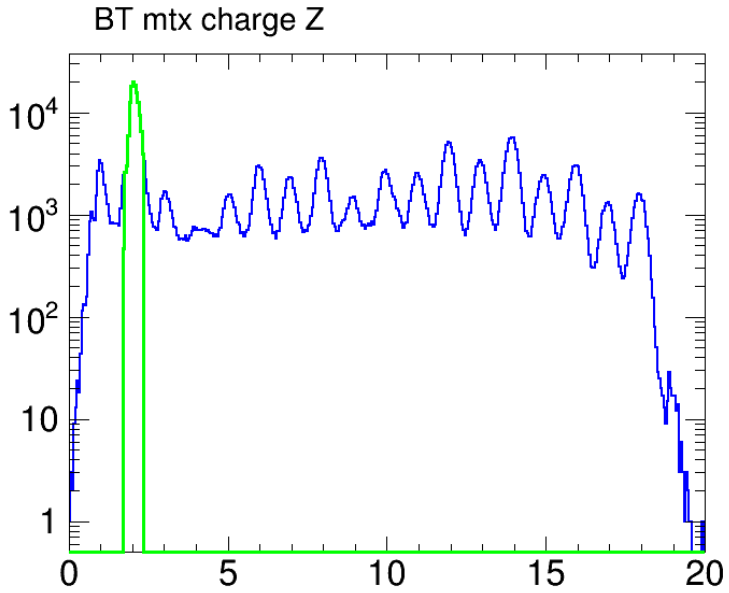




Charge selection using IC beam tracker:

- **mean of 4 maximum signals from silicon matrices included in the tracker as charge estimator of incoming ion**
- **this cut permits also a selection on the beam position**

Minimum biased Z Charge selection: 13 GeV/n & 19 GeV/n TB data

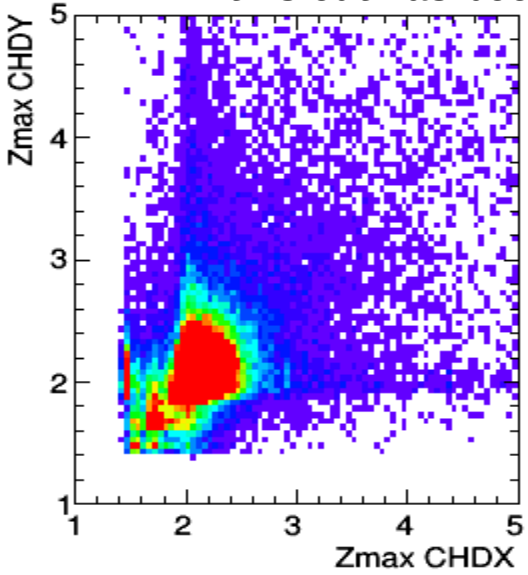


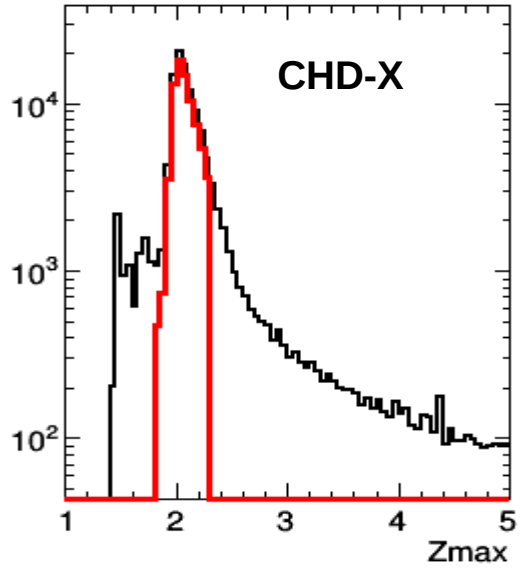
Charge preselection using IC beam tracker:

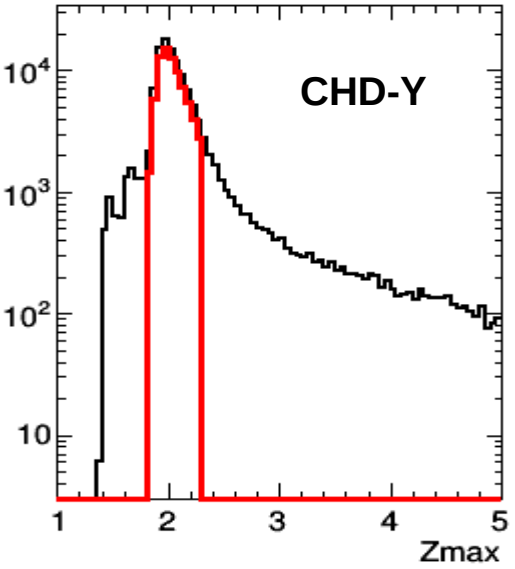
- **mean of 4 maximum signals from silicon matrices (blue plot);**
- **cut on helium peak (green plot);**

Final charge selection using CHD-X + CHD-Y maximum signals:

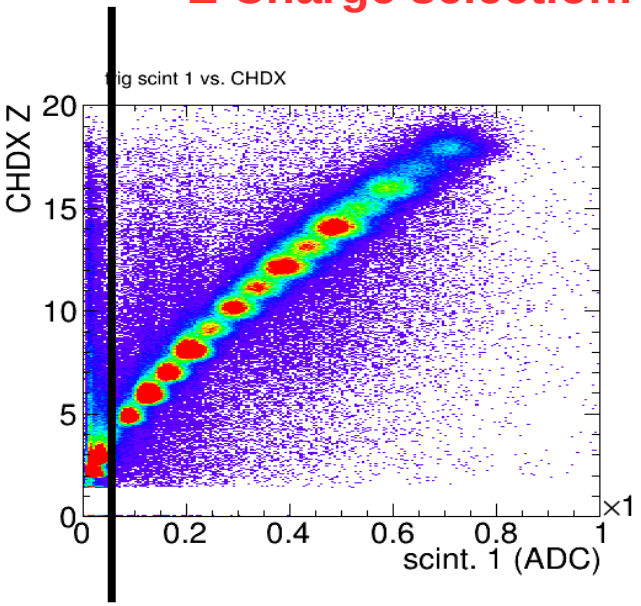
- **this cut has been applied alsot to MC data**

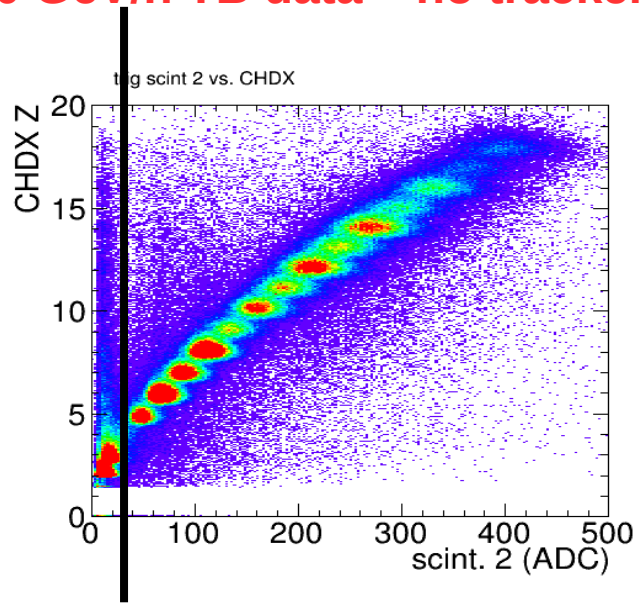






Z Charge selection: 150 GeV/n TB data – no tracker in front of CALET

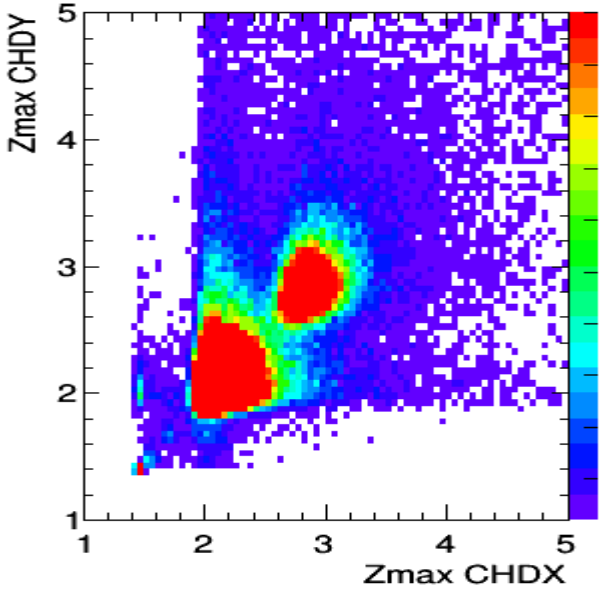


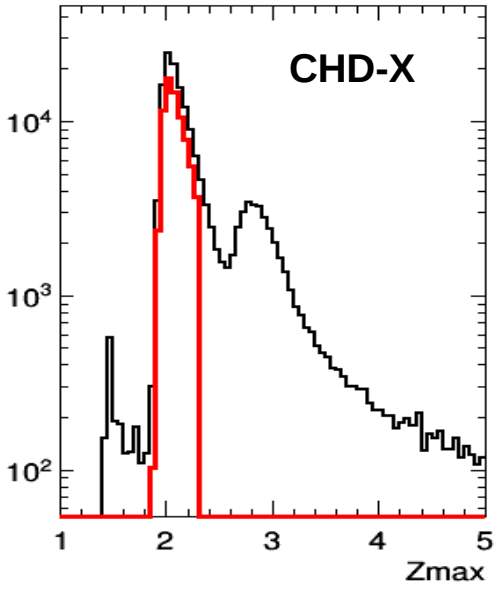


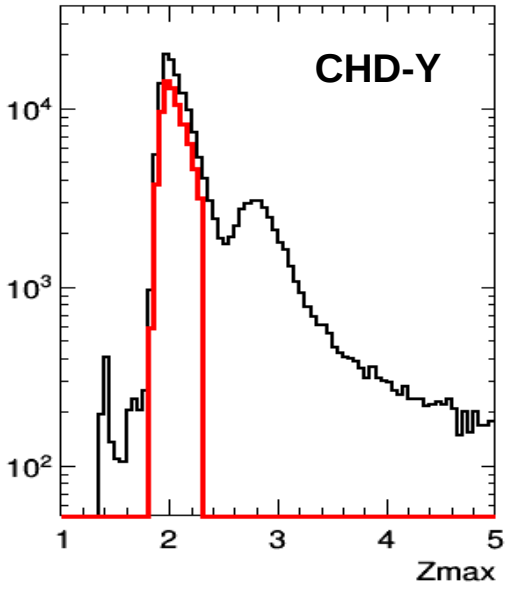
Charge preselection using signals from trigger scintillators

Final charge selection using CHD-X + CHD-Y:

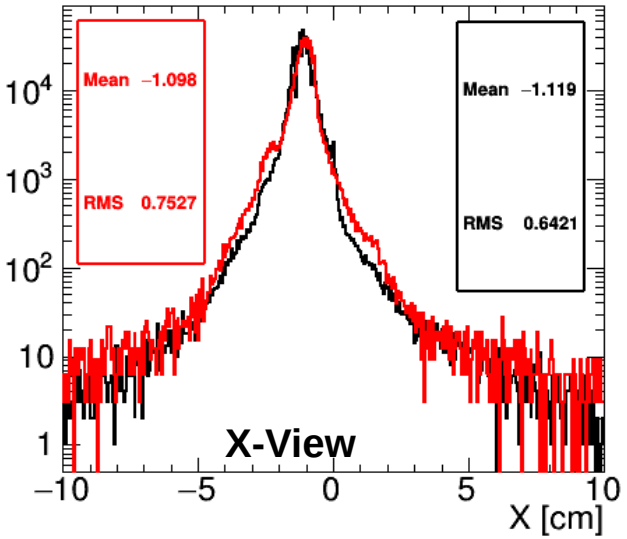
- **this cut has been applied alsot to MC data**

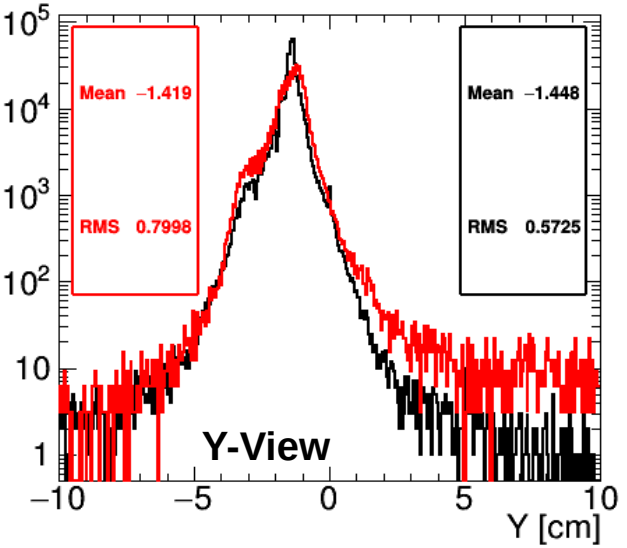




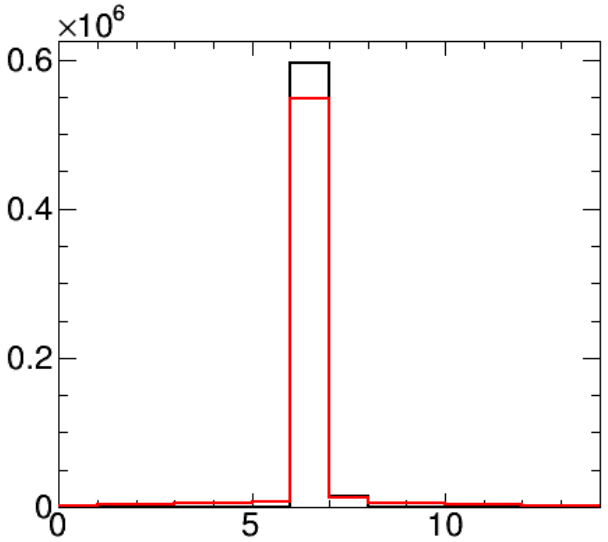


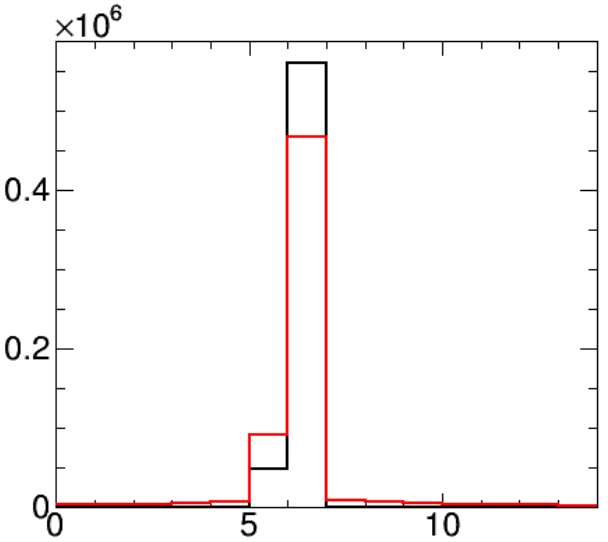
Minimum Biased Beam position selection (150 GeV/n – TB data vs Epics)





the MC beam spot reproduces quite well the real one (BT 2015)

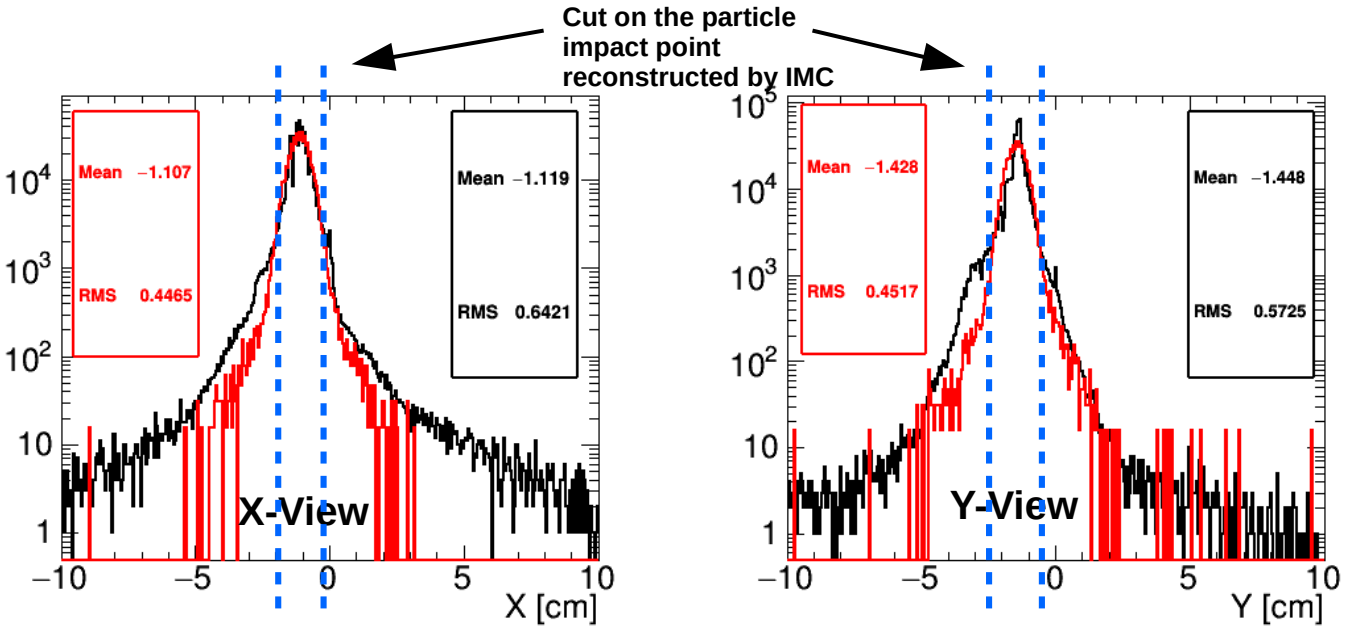




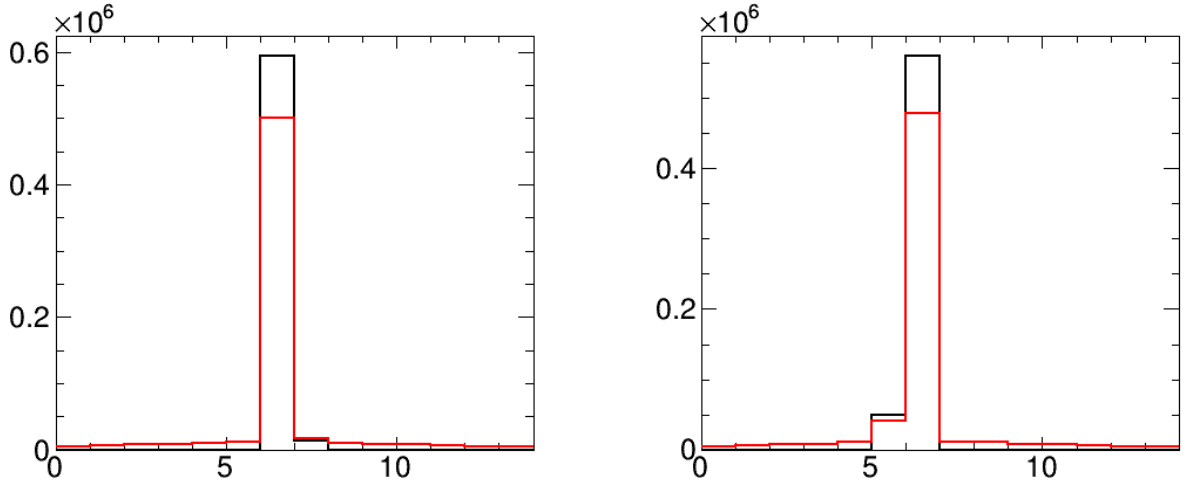
Red curve: MC simulation
Black dots: TB data

selection of the most populated paddles, from "position of maximum signal" histogram (both CHD-X and CHD-Y)

Minimum (??) Biased Beam position selection (150 GeV/n – TB data vs Fluka)



In this case, the MC beam spot is not so good with respect to the real one (BT 2015)



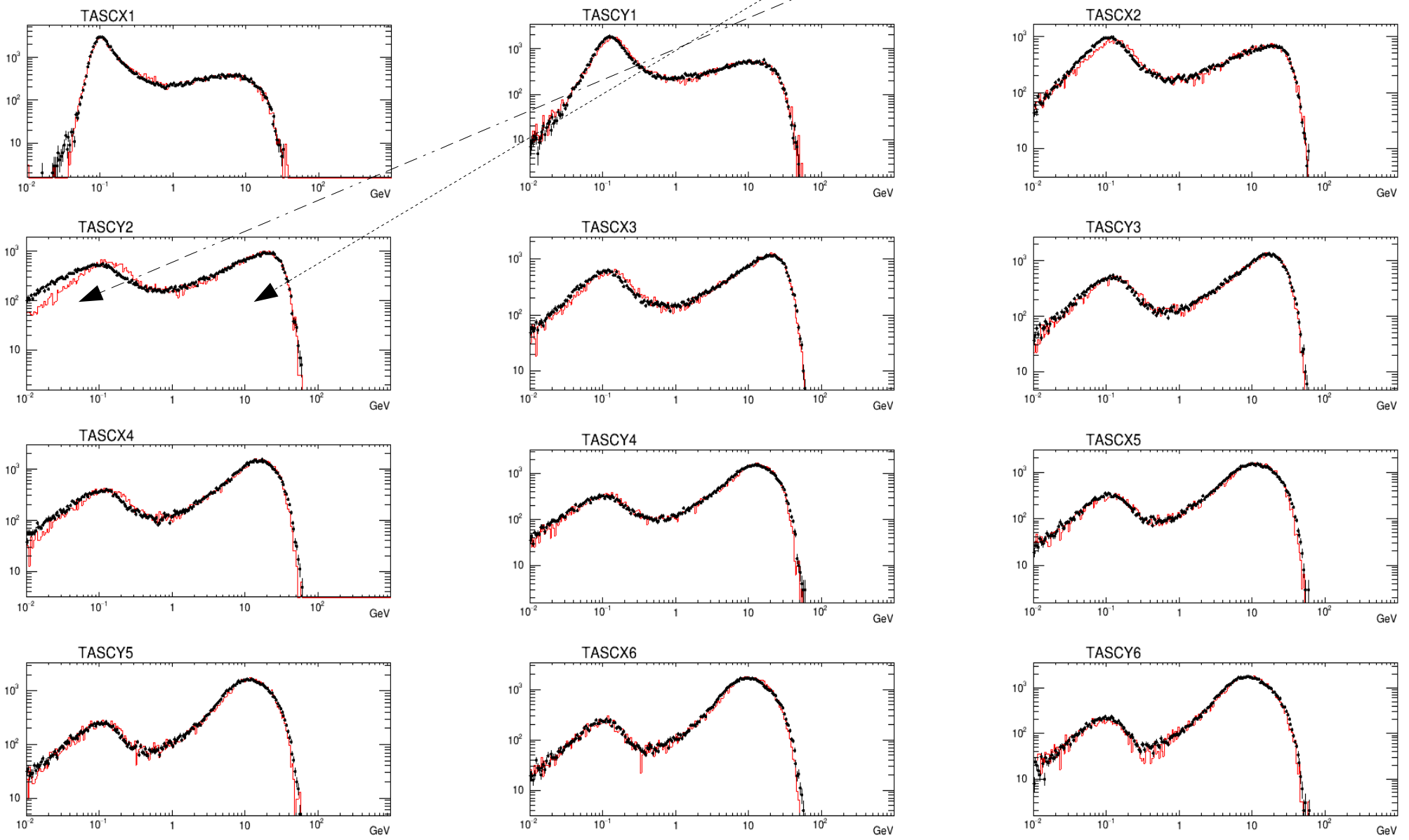
So the selection on the most populated paddles does not work well:
a selection cut using IMC tracking has been applied (possible bias introduced)

Study on Trigger Efficiency correction 1.
BT data vs Fluka

- **TASC calibration & MC digitization with Helium nuclei**
- **Only the minimum biased cuts applied**
- **Systematic errors estimated varying the charge selection cuts**

TASC layer Energy deposits: BT data vs FLUKA - 150 GeV/n helium

BT data & MC simulation agree quite well in shower region;
some discrepancies in the MIP region (look at TASC-Y2)

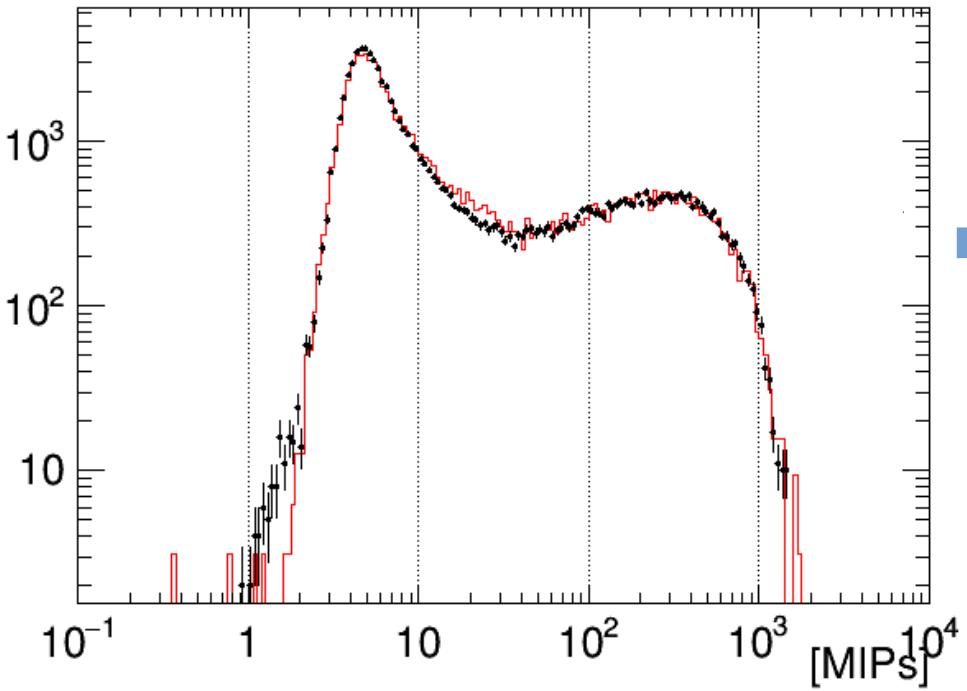


Red curve: MC simulation
Black dots: TB data

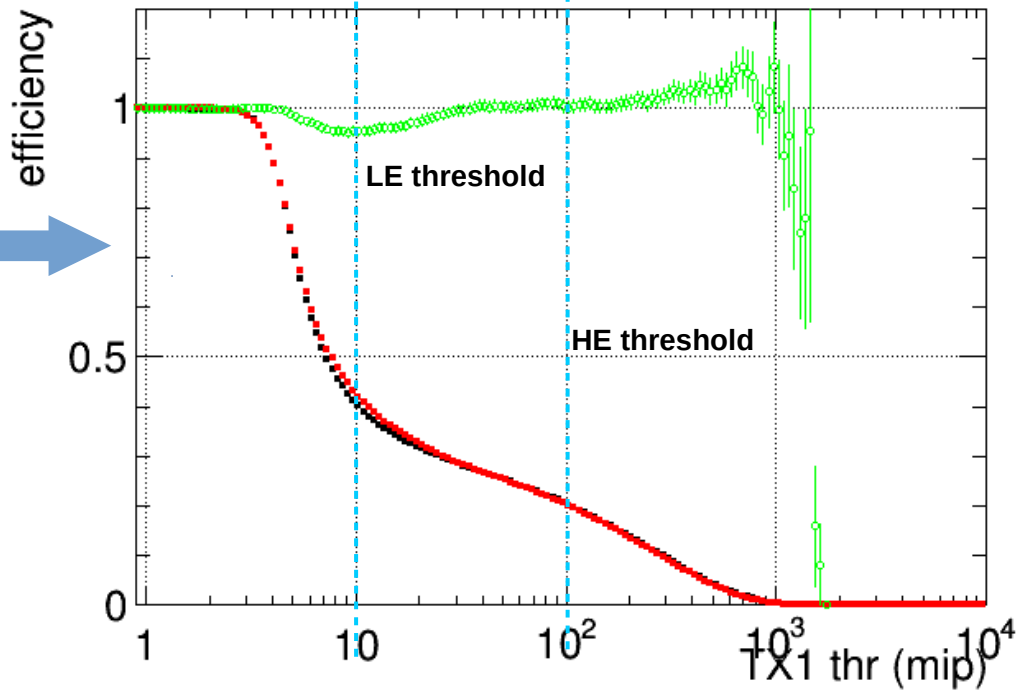
Trigger efficiency based on TASC-X1 energy deposit: BT data vs FLUKA - 150 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold

TASC-X1 Energy Deposit



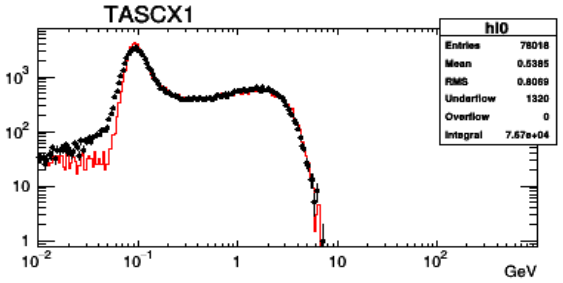
Trigger Efficiency vs Threshold

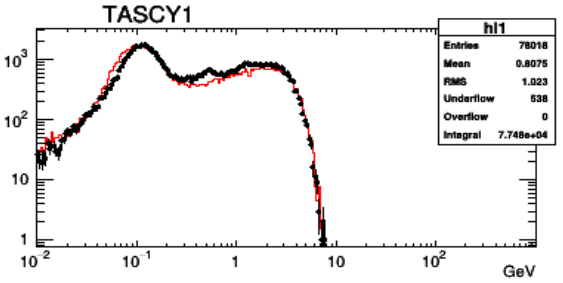


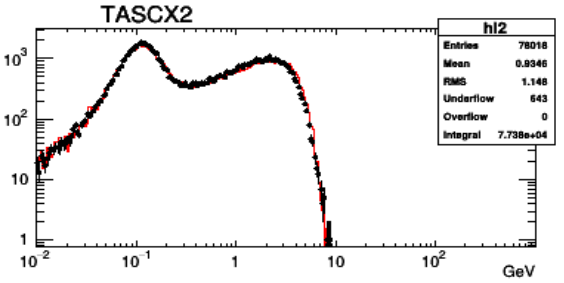
Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

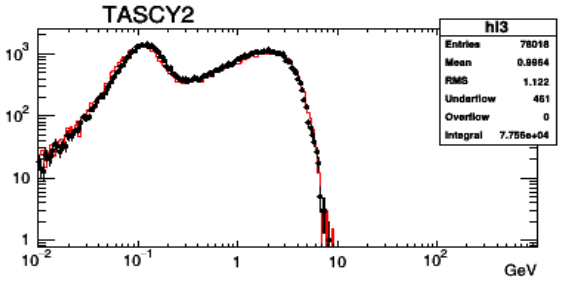
The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 0.955 +/- 0.010(stat) +/- 0.030(sys)
HE Trigger Efficiency correction: 1.005 +/- 0.013(stat) +/- 0.065(sys)

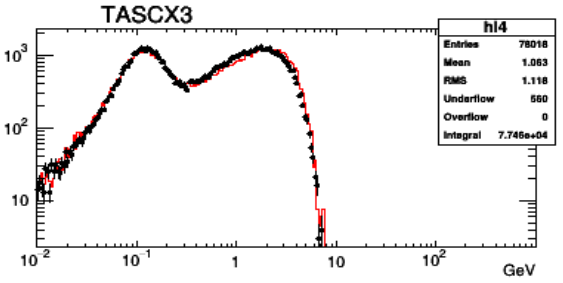
TASC layer Energy deposits:
BT data vs FLUKA - 19 GeV/n helium

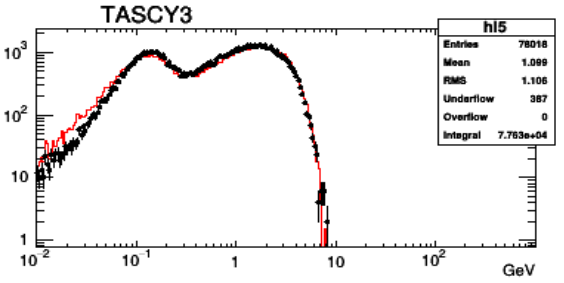


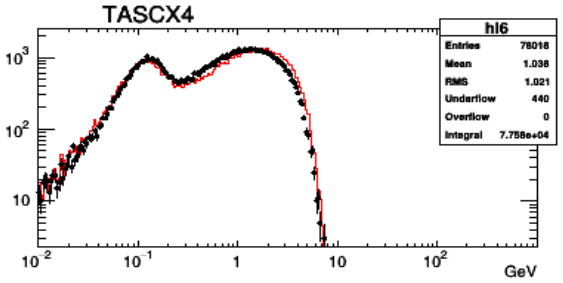


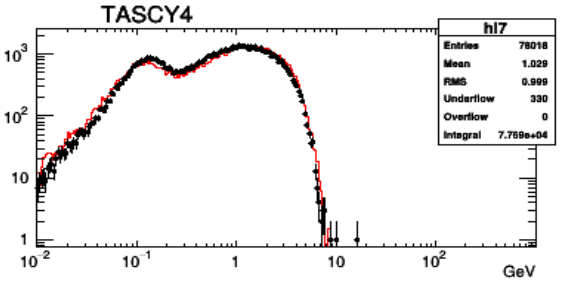


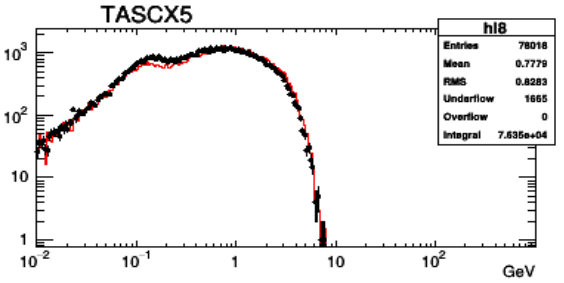


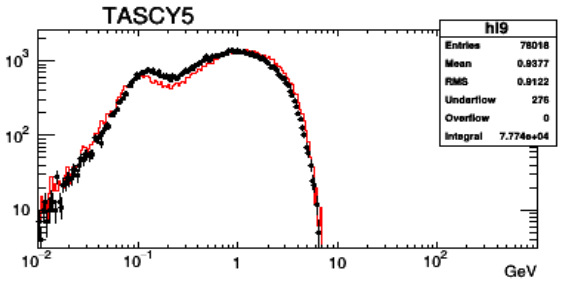


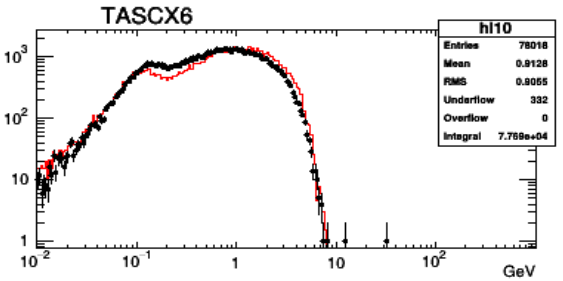


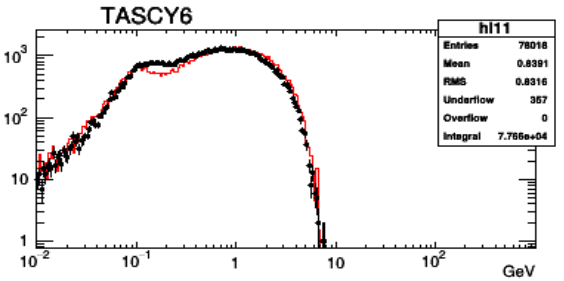










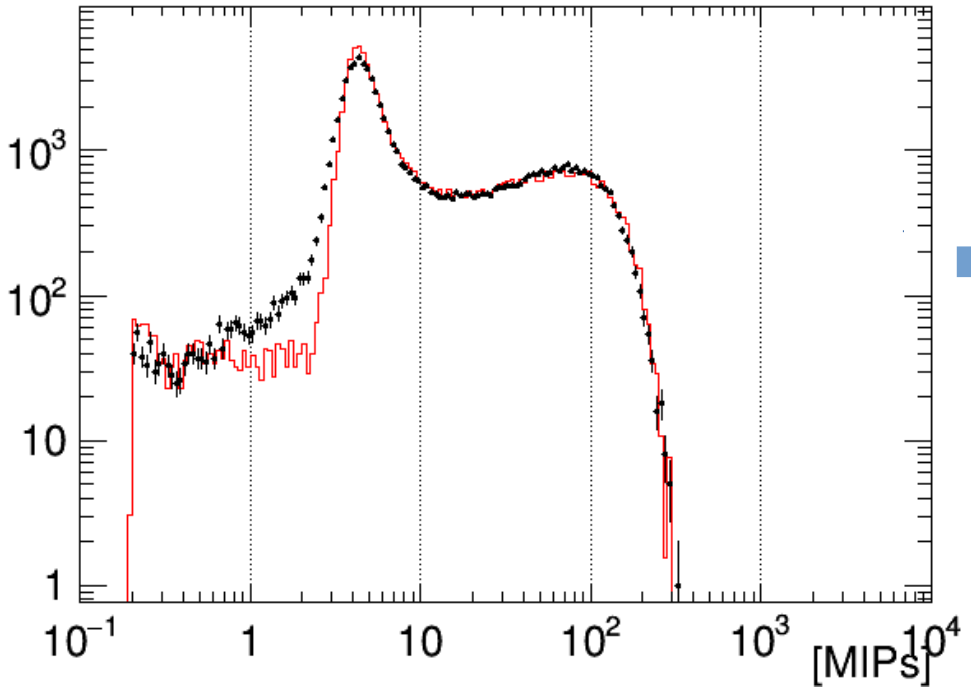


Red curve: MC simulation
Black dots: TB data

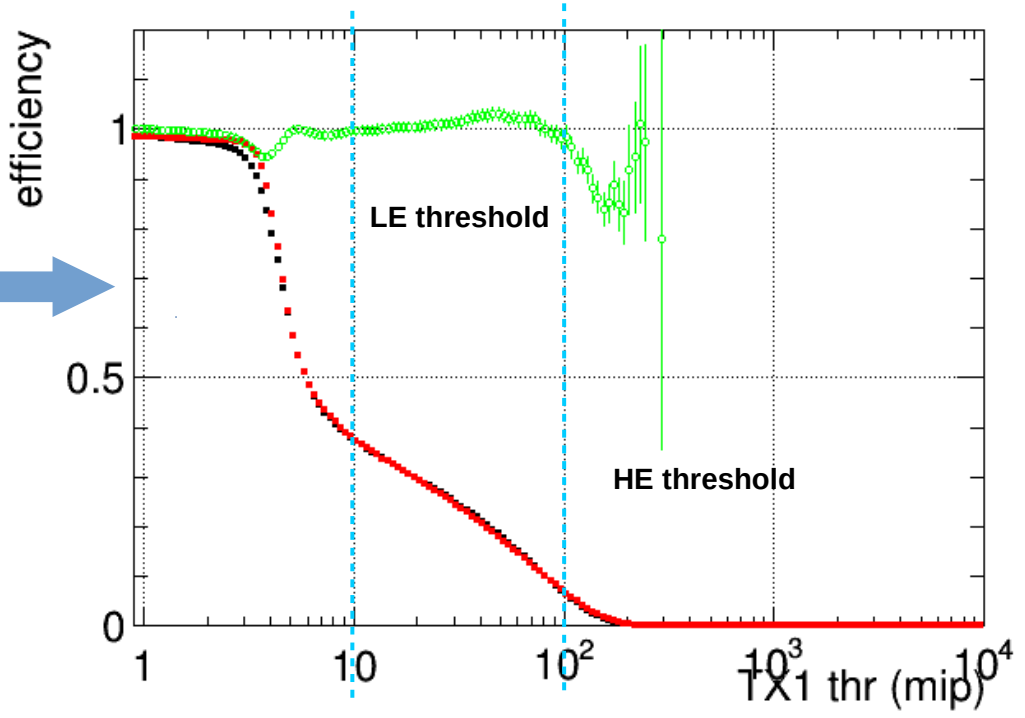
Trigger efficiency based on TASC-X1 energy deposit: BT data vs FLUKA - 19 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold

TASC-X1 Energy Deposit



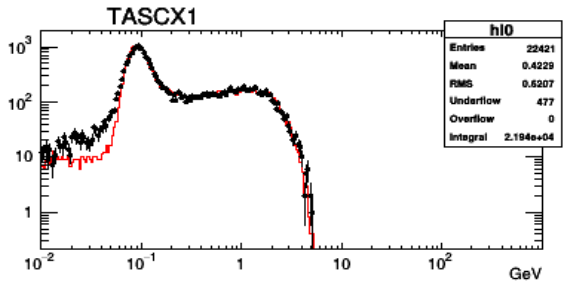
Trigger Efficiency vs Threshold

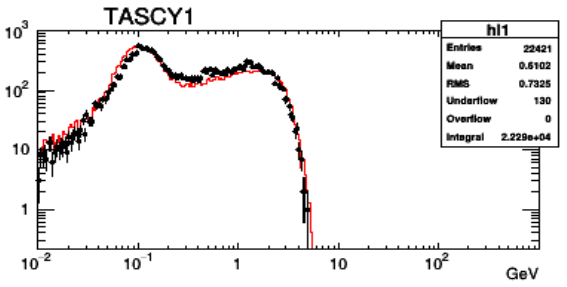


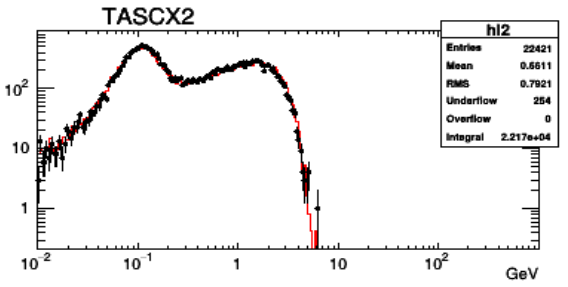
Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

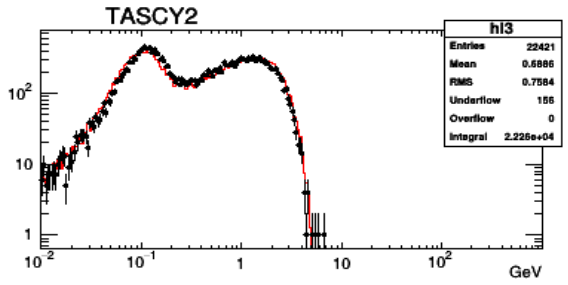
The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 0.996 +/- 0.010(stat) +/- 0.025(sys)
HE Trigger Efficiency correction: 0.981 +/- 0.020(stat) +/- 0.050(sys)

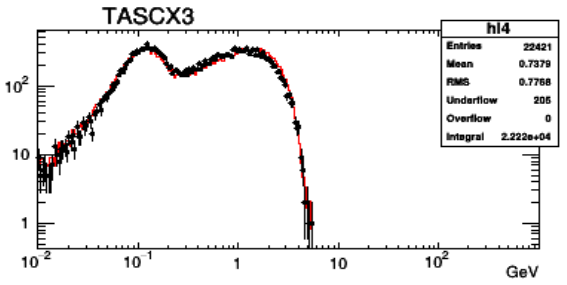
TASC layer Energy deposits: BT data vs FLUKA - 13 GeV/n helium

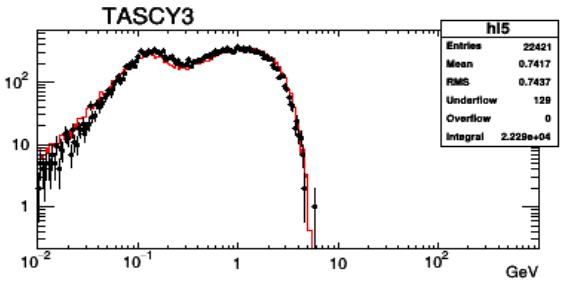


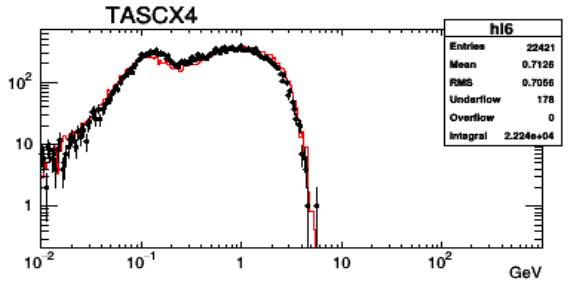


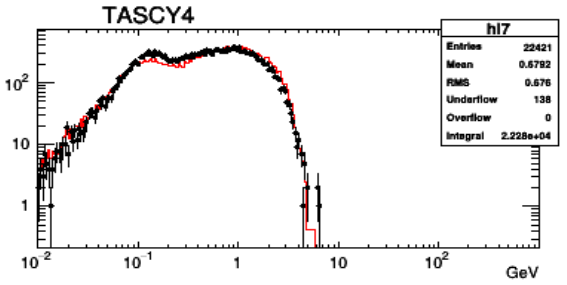


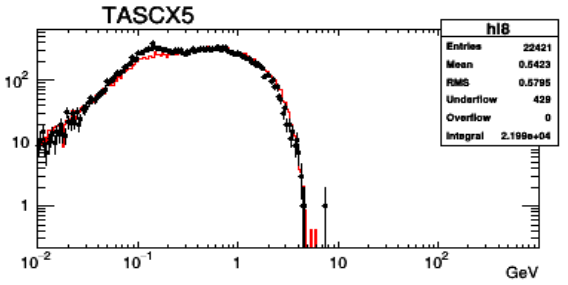


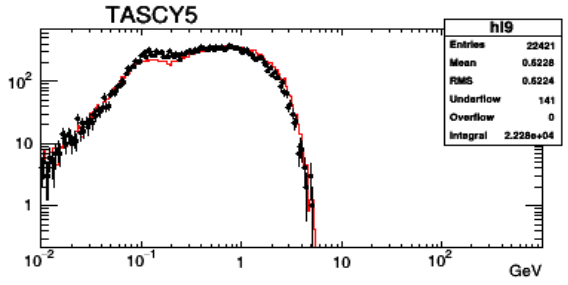


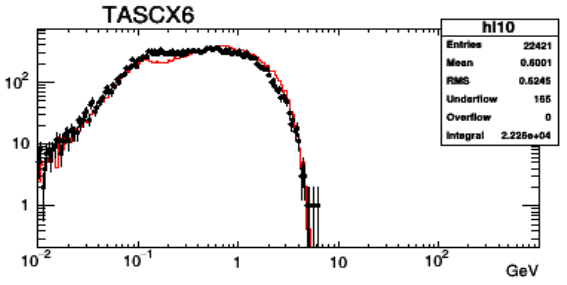


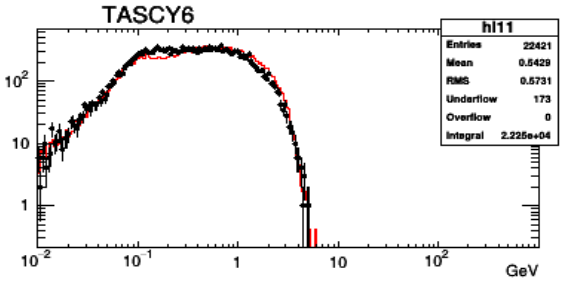








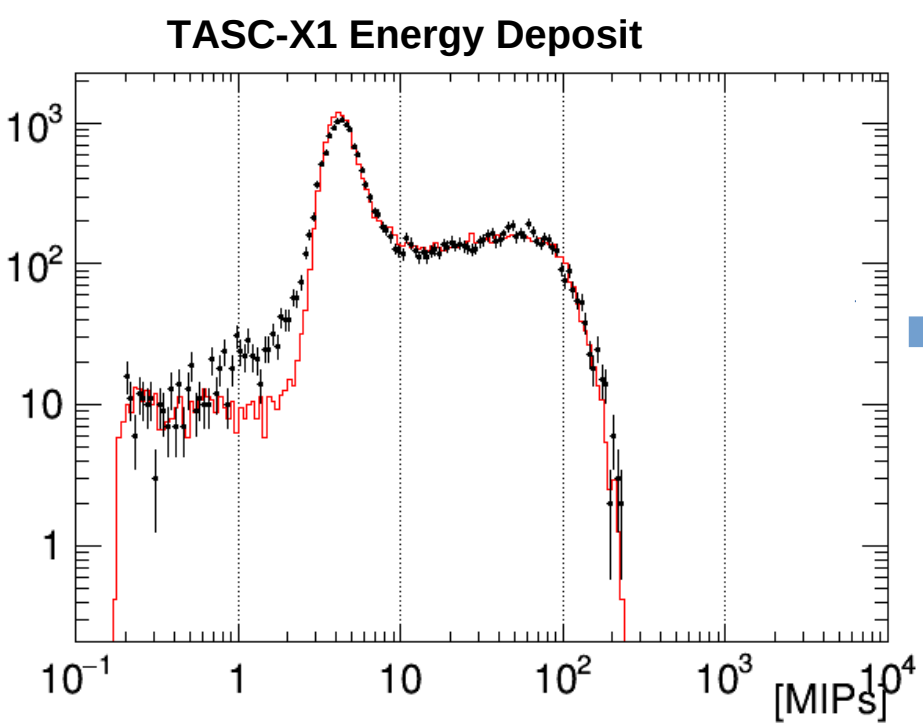


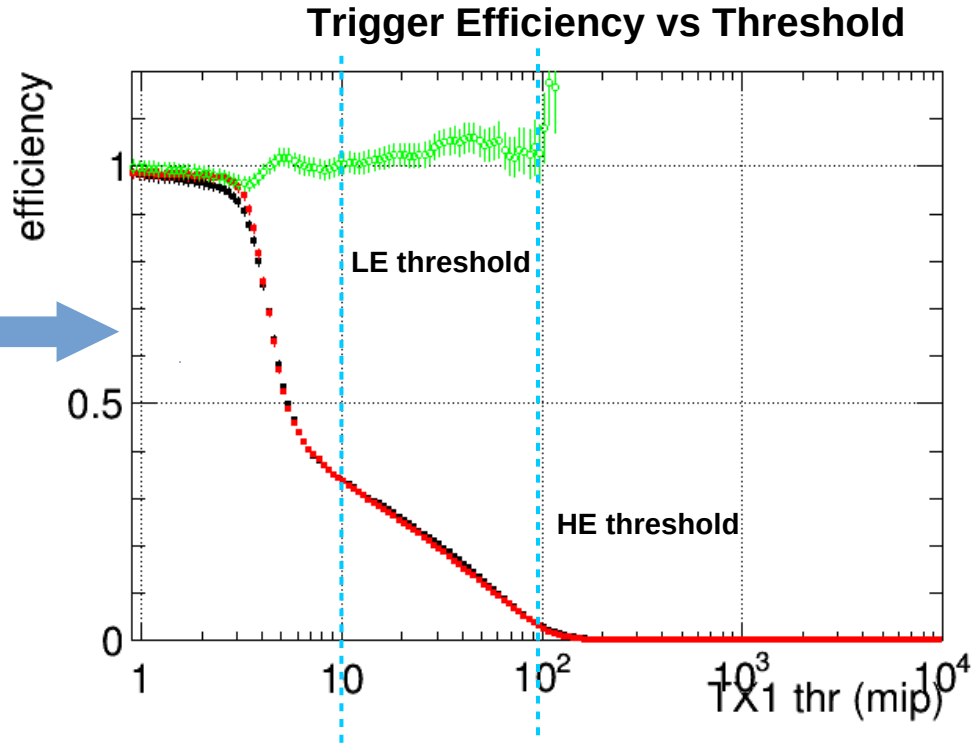


Red curve: MC simulation
Black dots: TB data

Trigger efficiency based on TASC-X1 energy deposit: BT data vs FLUKA - 13 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold





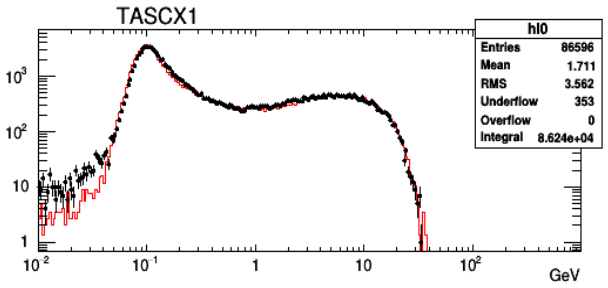
Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

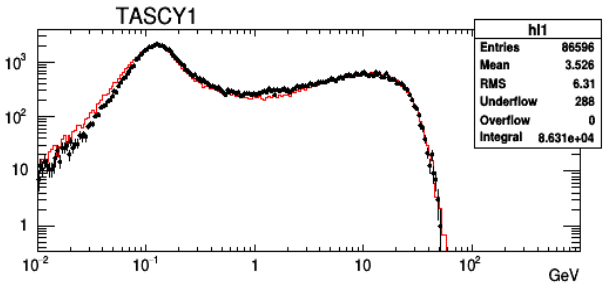
The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 1.003 +/- 0.020(stat) +/- 0.025(sys)
HE Trigger Efficiency correction: 1.027 +/- 0.062(stat) +/- 0.080(sys)

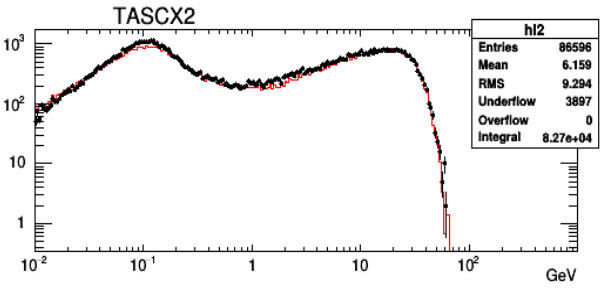
Study on Trigger Efficiency correction 2.
BT data vs Epics

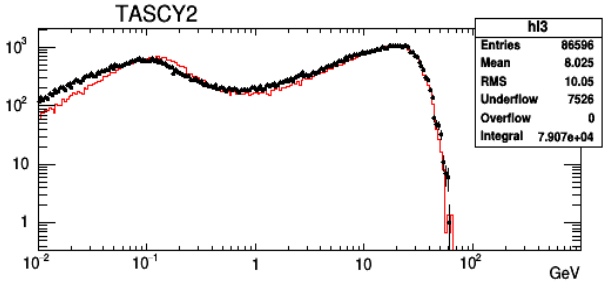
- **TASC calibration & MC digitization with Helium nuclei**
- **Only the minimum biased cuts applied**
- **Systematic errors estimated varying the charge selection cuts**

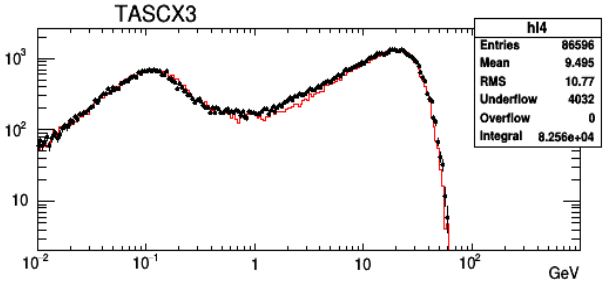
TASC layer Energy deposits: BT data vs EPICS - 150 GeV/n helium

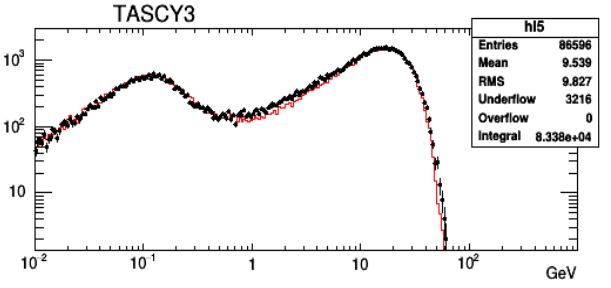


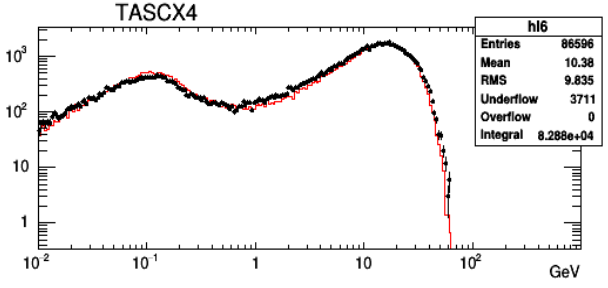


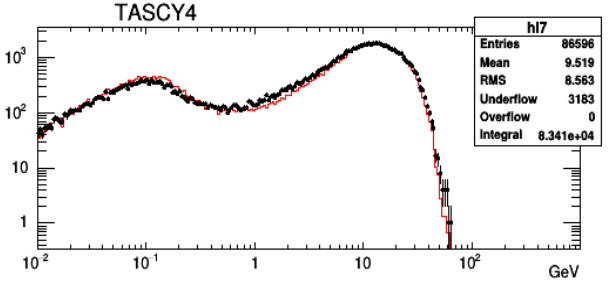


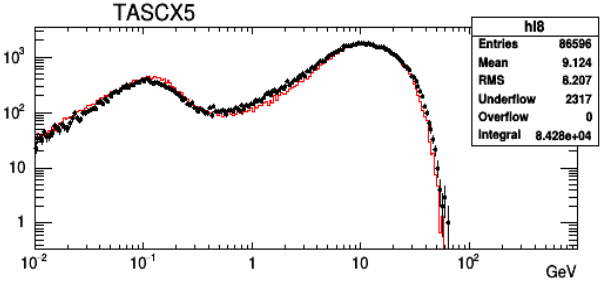


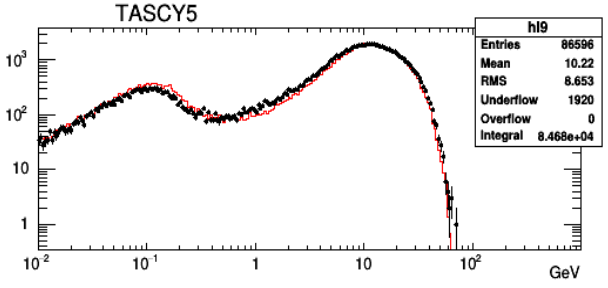


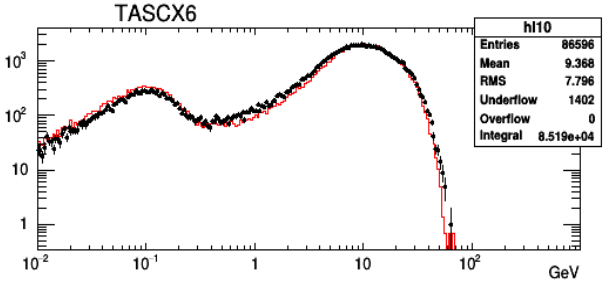


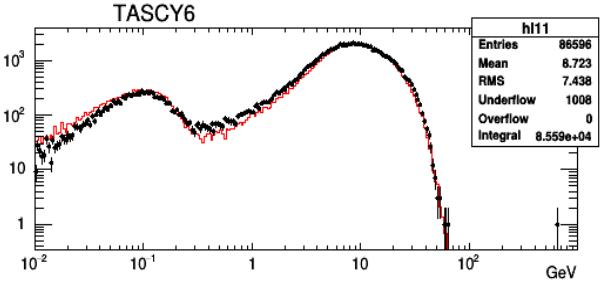








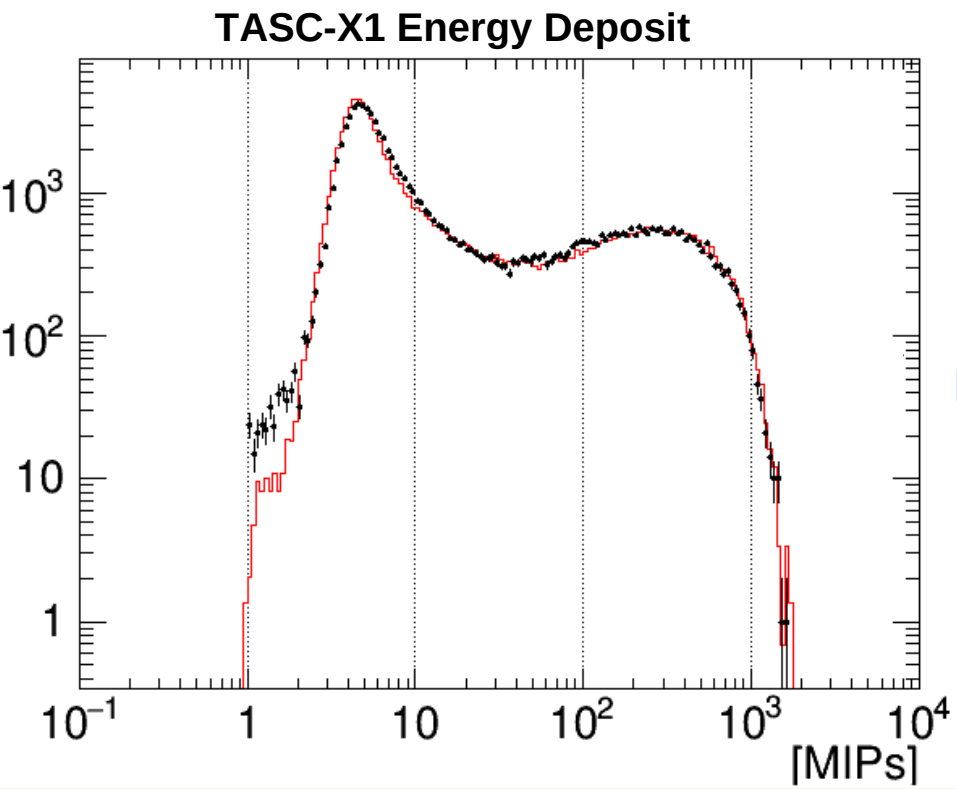


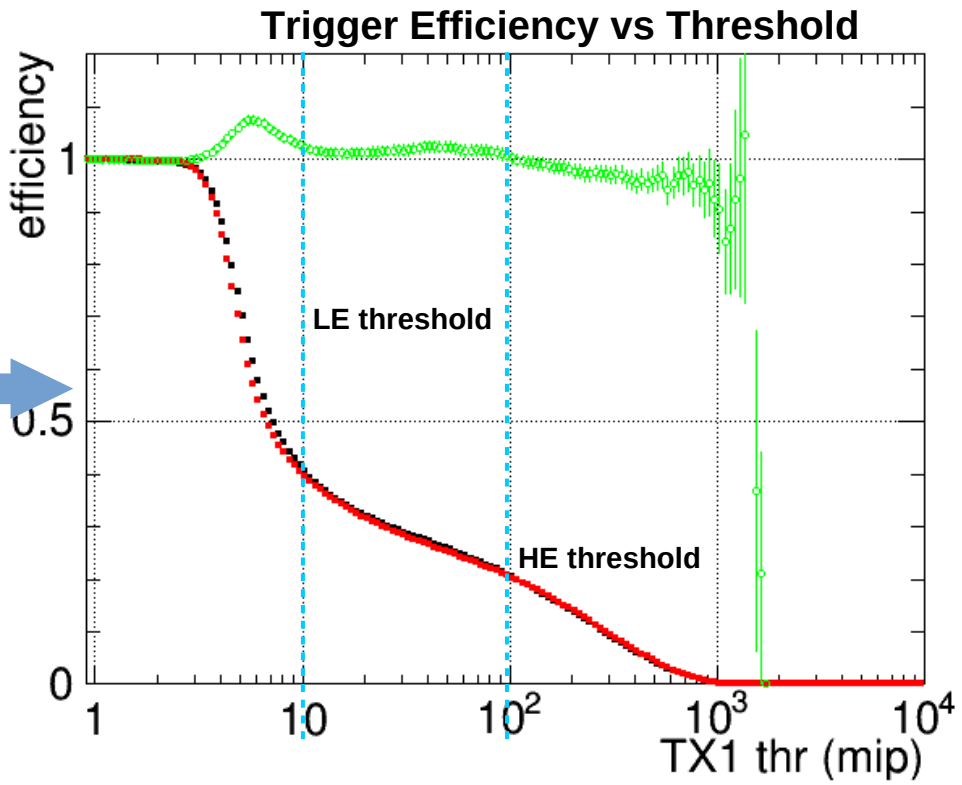


Red curve: MC simulation
Black dots: TB data

Trigger efficiency based on TASC-X1 energy deposit: BT data vs EPICS - 150 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold

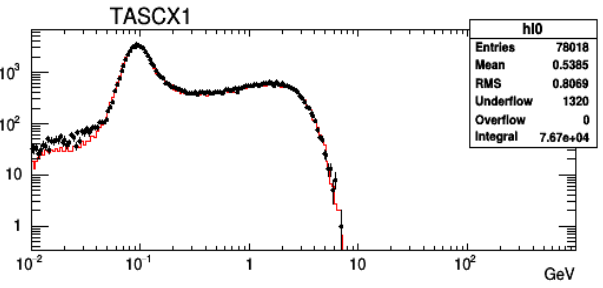


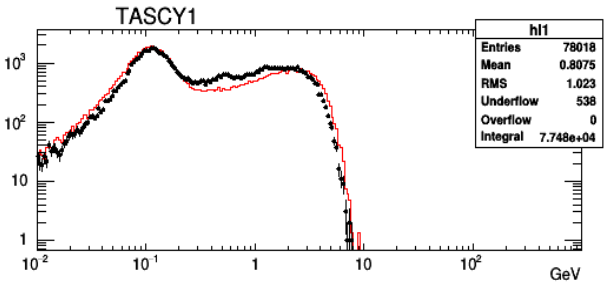


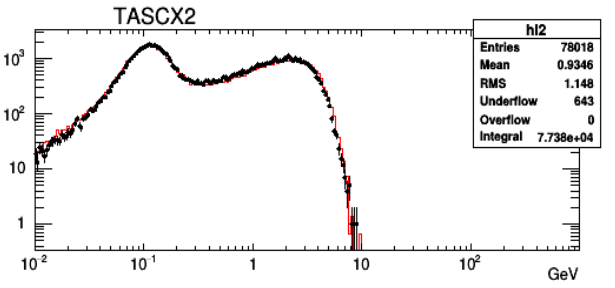
Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

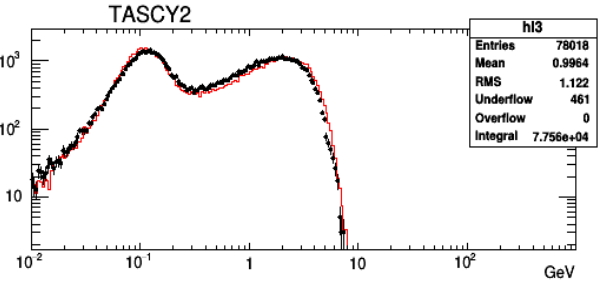
The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 1.023 +/- 0.010(stat) +/- 0.070(sys)
HE Trigger Efficiency correction: 1.008 +/- 0.012(stat) +/- 0.123(sys)

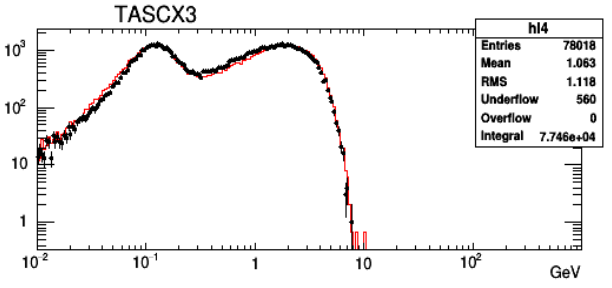
TASC layer Energy deposits: BT data vs EPICS - 19 GeV/n helium

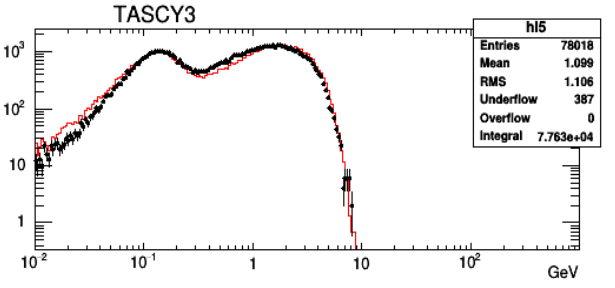


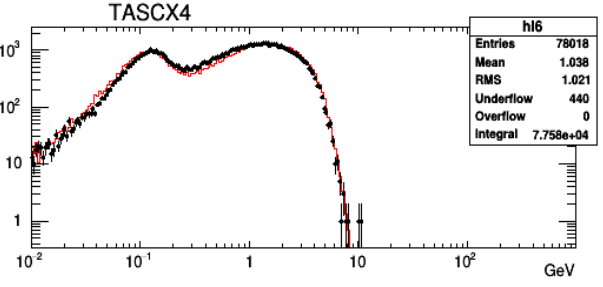


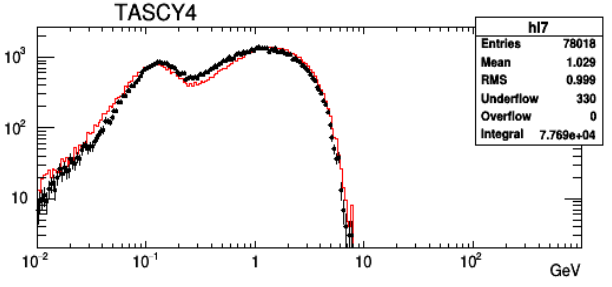


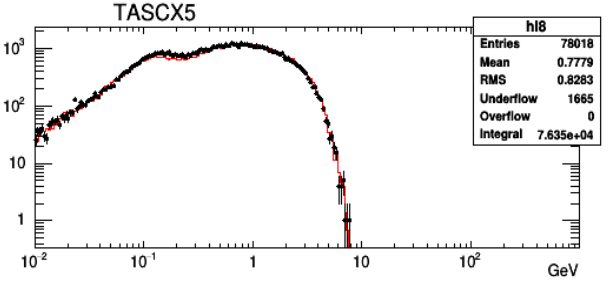


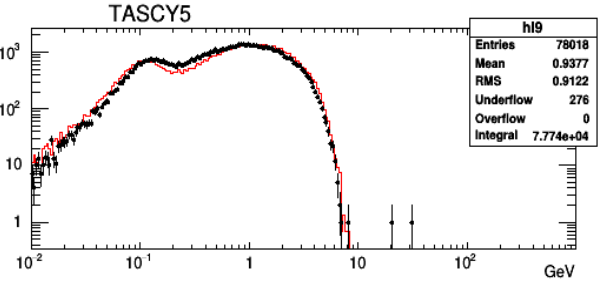


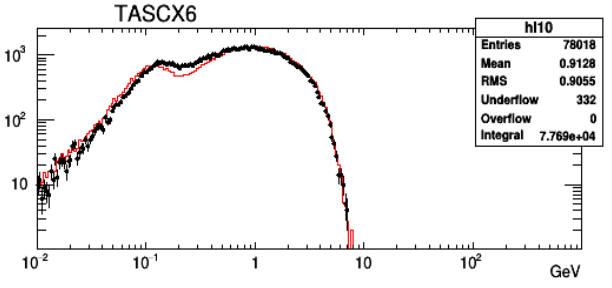


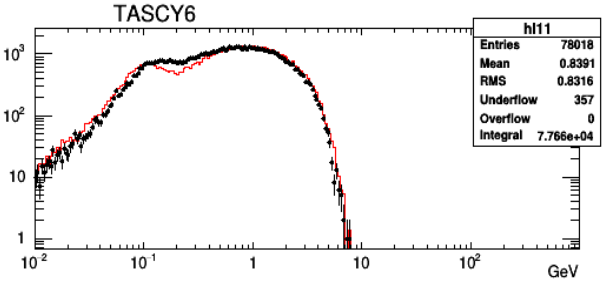








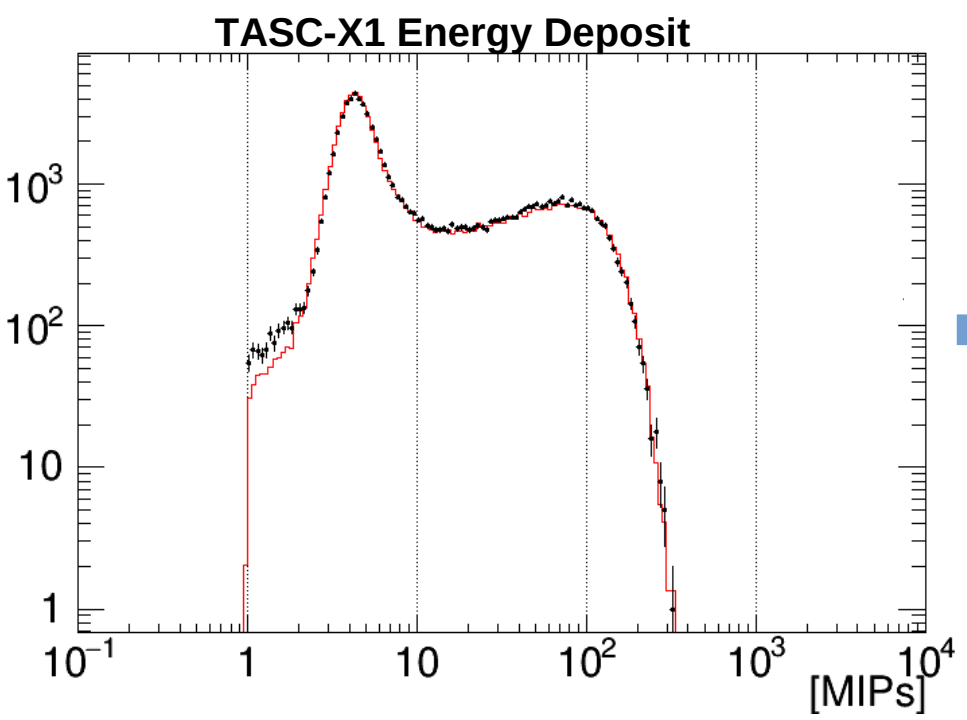


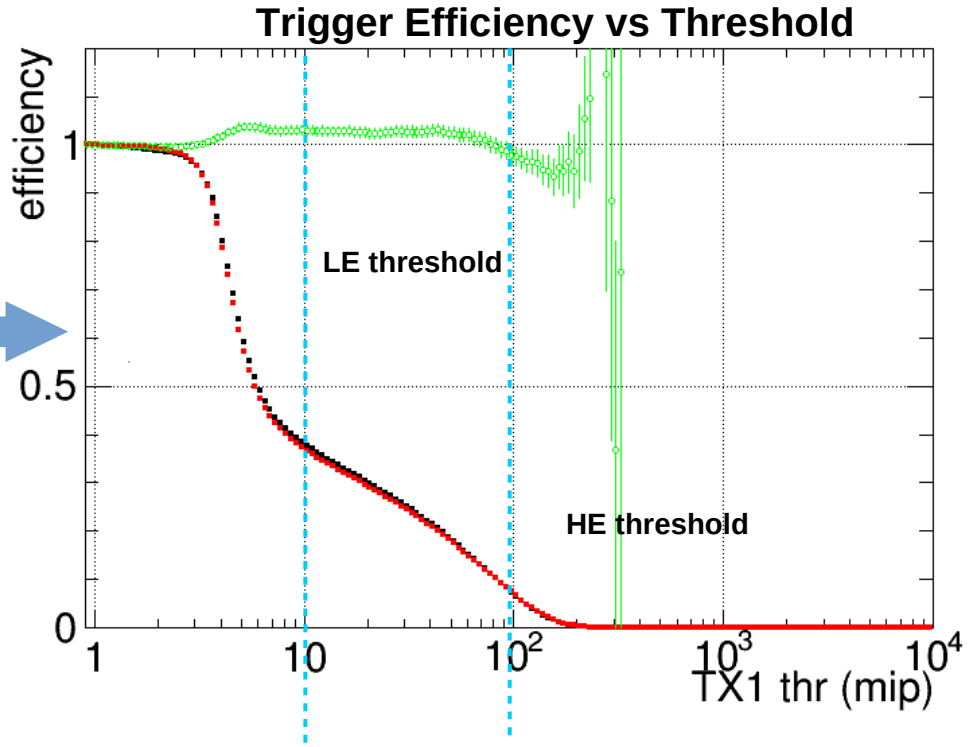


Red curve: MC simulation
Black dots: TB data

Trigger efficiency based on TASC-X1 energy deposit: BT data vs EPICS - 19 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold

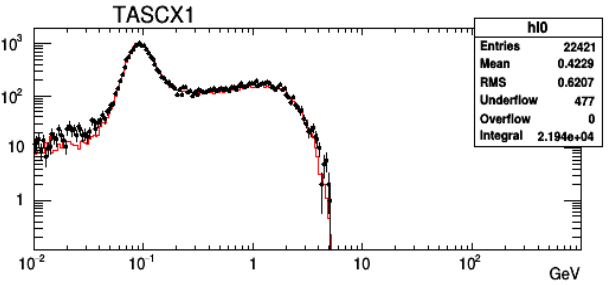


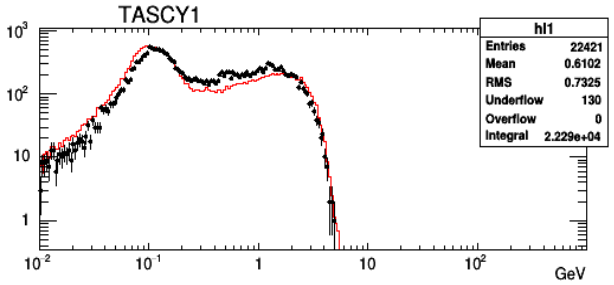


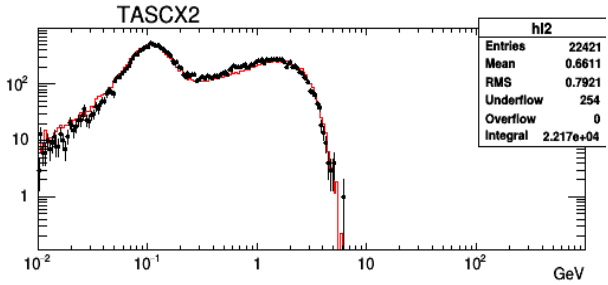
Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

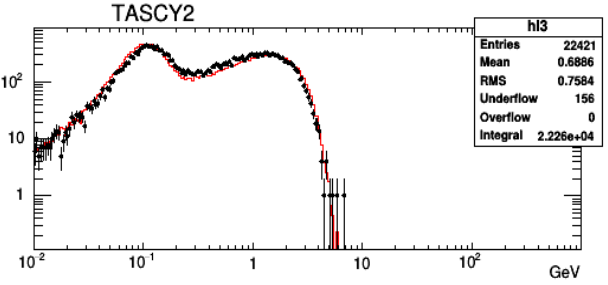
The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 1.031 +/- 0.010(stat) +/- 0.057(sys)
HE Trigger Efficiency correction: 0.979 +/- 0.020(stat) +/- 0.087(sys)

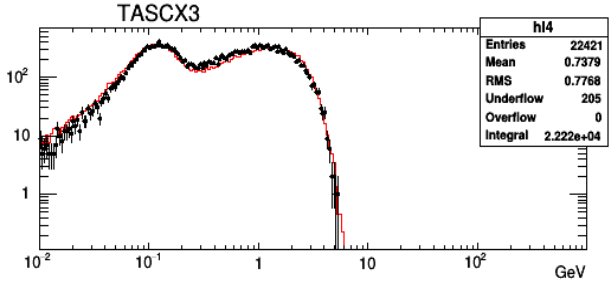
TASC layer Energy deposits:
BT data vs EPICS - 13 GeV/n helium

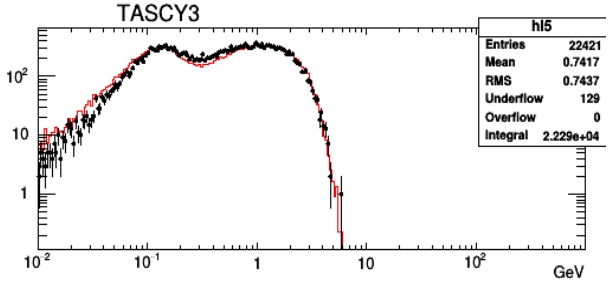


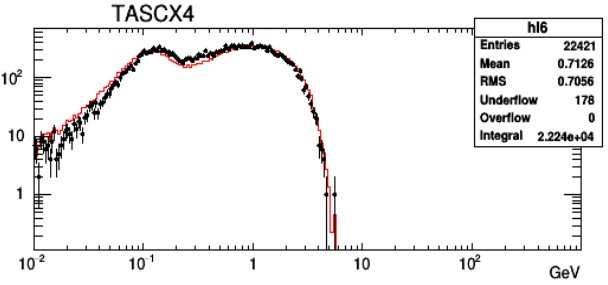


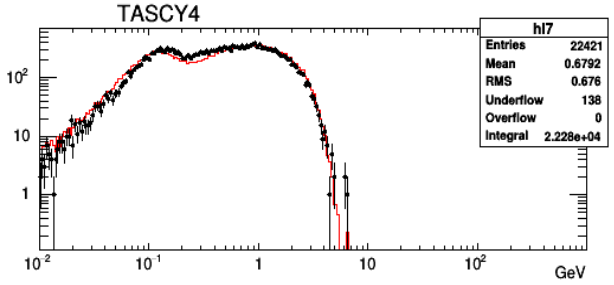


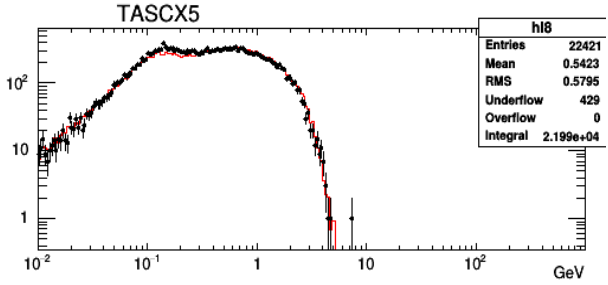


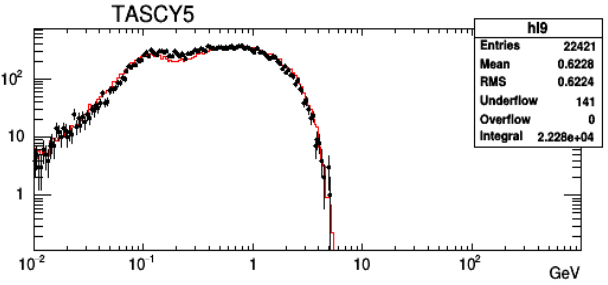


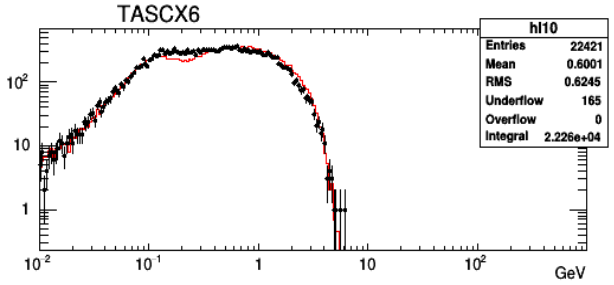


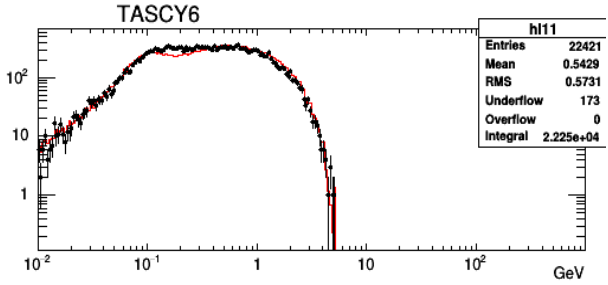








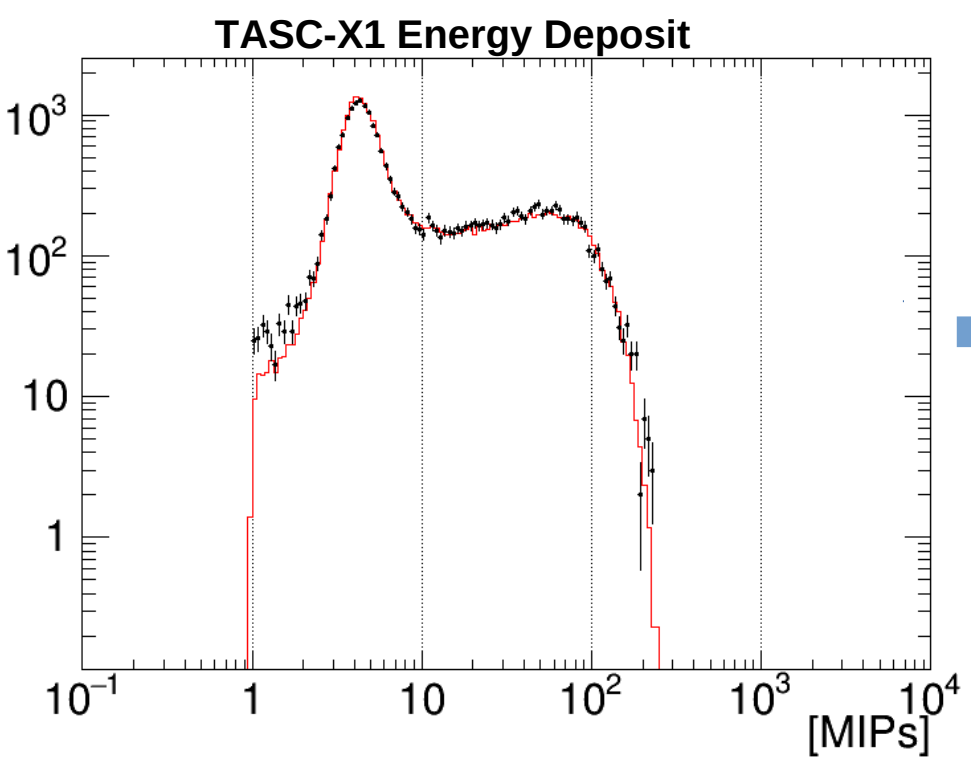


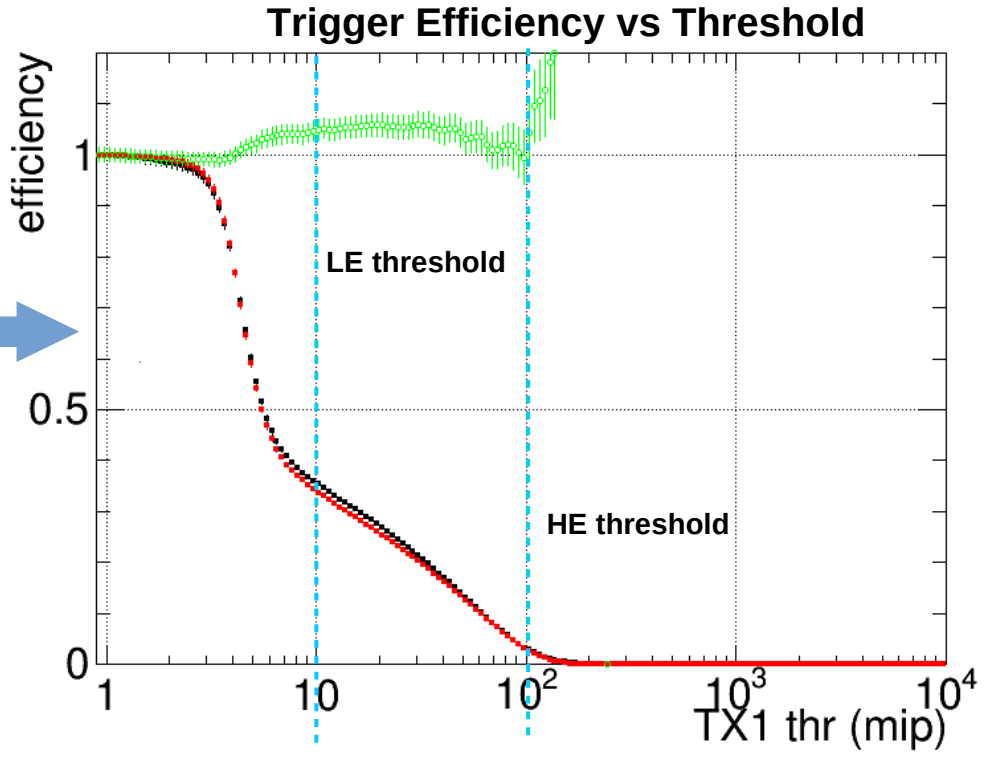


Red curve: MC simulation
Black dots: TB data

Trigger efficiency based on TASC-X1 energy deposit: BT data vs EPICS - 13 GeV/n helium

For each plot we can build the trigger efficiency distribution:
(number of events above a certain threshold)/(total number of events) vs Threshold

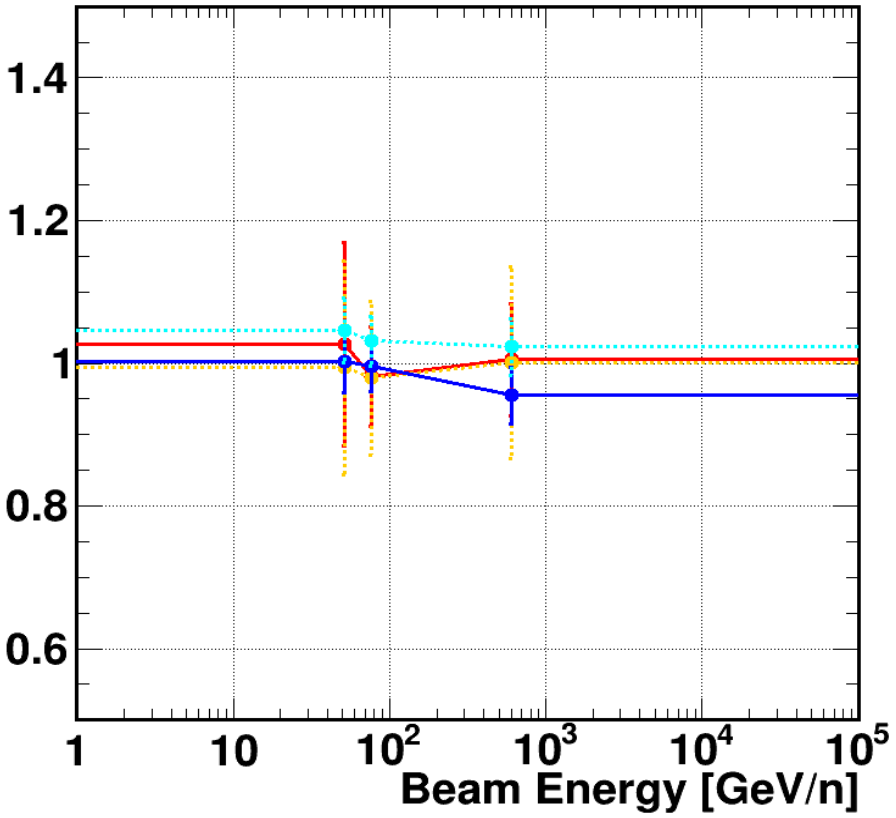




Red curve: MC simulation
Black squares: data
Green squares: ratio BT/MC

The ratio (data/MC) of the two distributions is an estimation of the correction:
LE Trigger efficiency correction: 1.046+/- 0.020(stat) +/- 0.071(sys)
HE Trigger Efficiency correction: 0.994 +/- 0.053(stat) +/- 0.097(sys)

Results: TB data vs Fluka/Epics



Red dots: HE trigger (Fluka)
Blue dots: LE trigger (Fluka)
Orange dots: HE trigger (Epics)
Blue dots: LE trigger (Epics)

Fluka – Trigg Eff correction

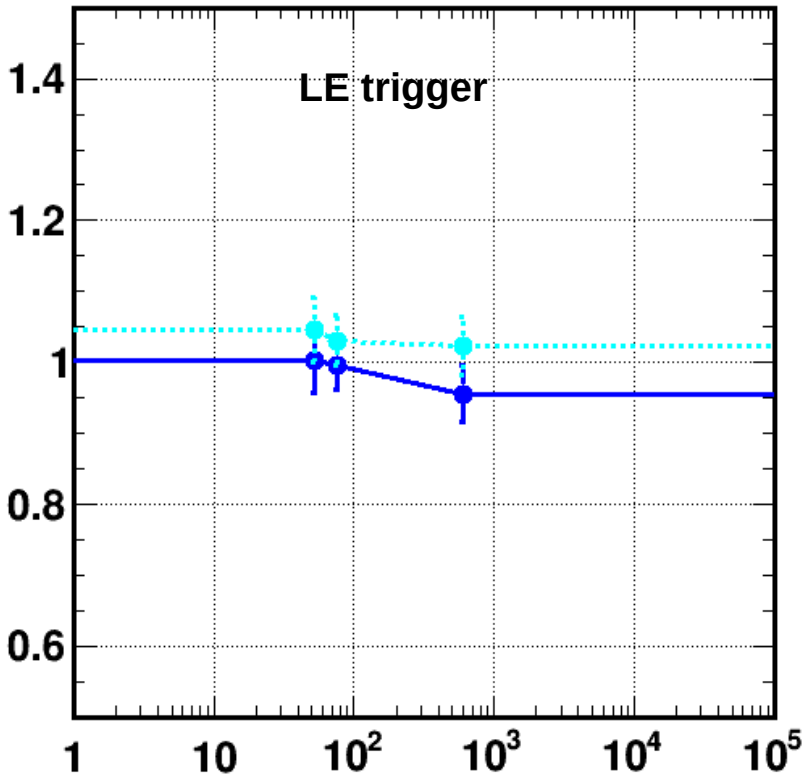
Beam Energy/n	Ratio HE	Ratio HE Error (stat+sys)	Ratio LE	Ratio LE Error (stat+sys)
13	1.027	0.142	1.003	0.045
19	0.981	0.070	0.996	0.035
150	1.005	0.078	0.955	0.040

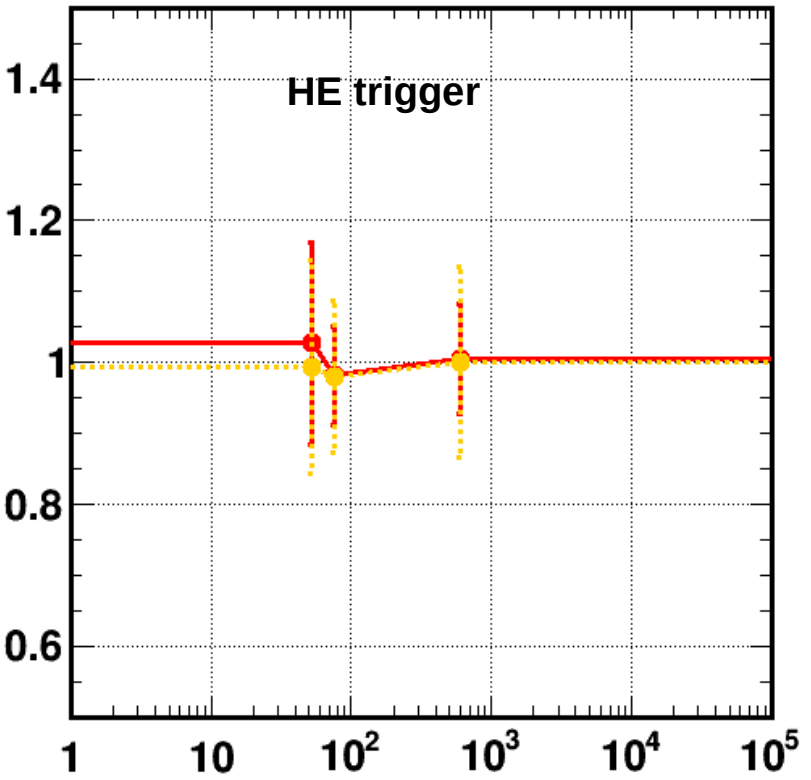
Epics – Trigg Eff correction

Beam Energy/n	Ratio HE	Ratio HE Error (stat+sys)	Ratio LE	Ratio LE Error (stat+sys)
13	0.994	0.150	1.046	0.091
19	0.979	0.107	1.031	0.067
150	1.008	0.135	1.023	0.080

The results seem compatible with 1, i.e no corrections, (in particular in the FLUKA case) within the errors;
There are large systematic errors from charge cut.

Results: TB data vs Fluka/Epics (2)





Red dots: HE trigger (Fluka)
Blue dots: LE trigger (Fluka)
Orange dots: HE trigger (Epics)
Blue dots: LE trigger (Epics)

Zoom on the results:

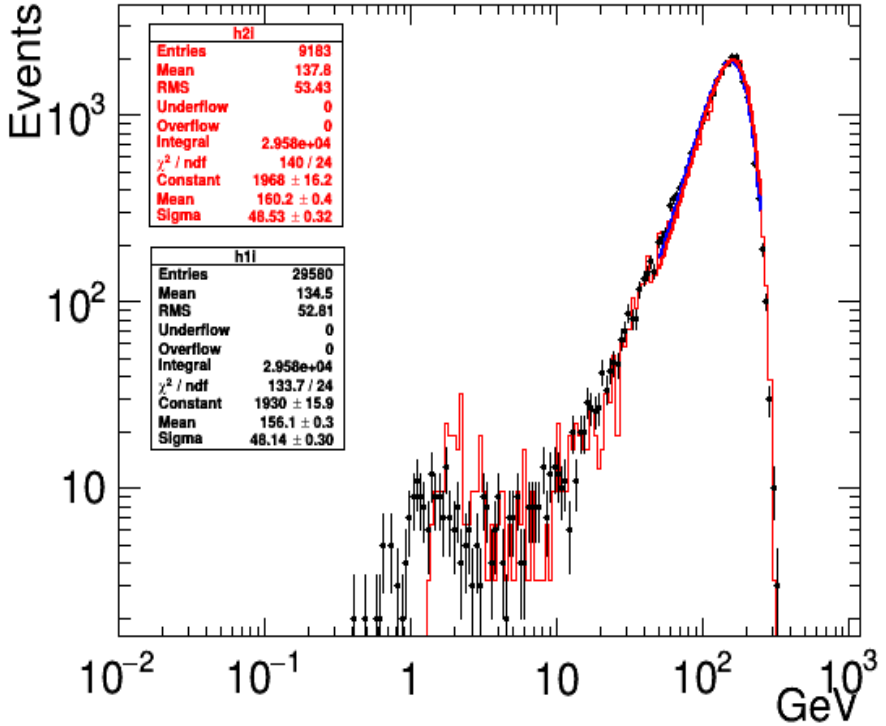
- **HE trigger – FLUKA and EPICS are in good agreement with each other and consistent with no corrections;**
- **LE trigger – FLUKA and EPICS agree within the errors and are consistent with no corrections;**
  - **a systematic shift between Epics and FLUKA (?)**

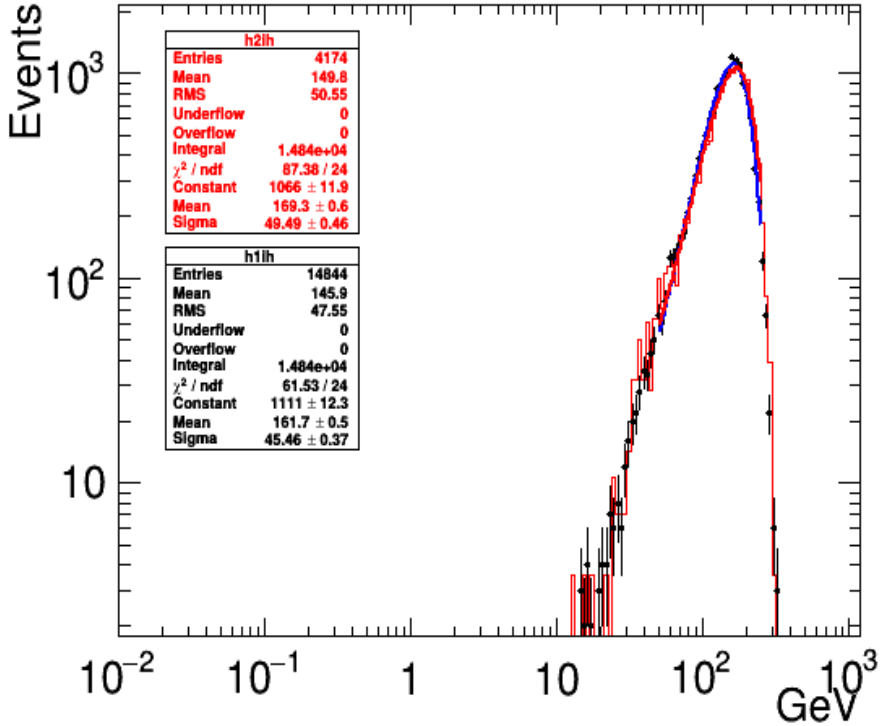
Study on Energy Scale correction 1.
BT data vs Fluka

- **TASC calibration & MC digitization with Helium nuclei**
- **Only the minimum biased cuts applied**
- **Systematic errors estimated varying the charge selection cuts**

TASC total energy deposit - 150 GeV/n helium
10 MIP threshold & 100 MIP threshold
Fluka vs TB data

After the trigger threshold application, the correction on absolute energy scale can be estimated from the ratio between means of the two distributions (MC & Data) and/or the ratio of the peak postion (from gaussian fit).

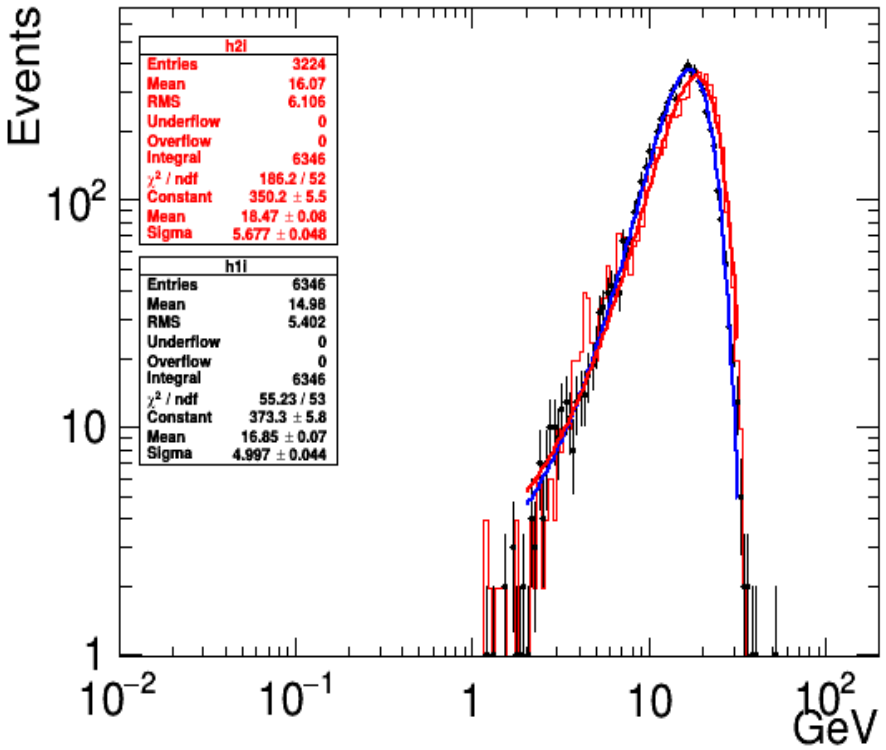


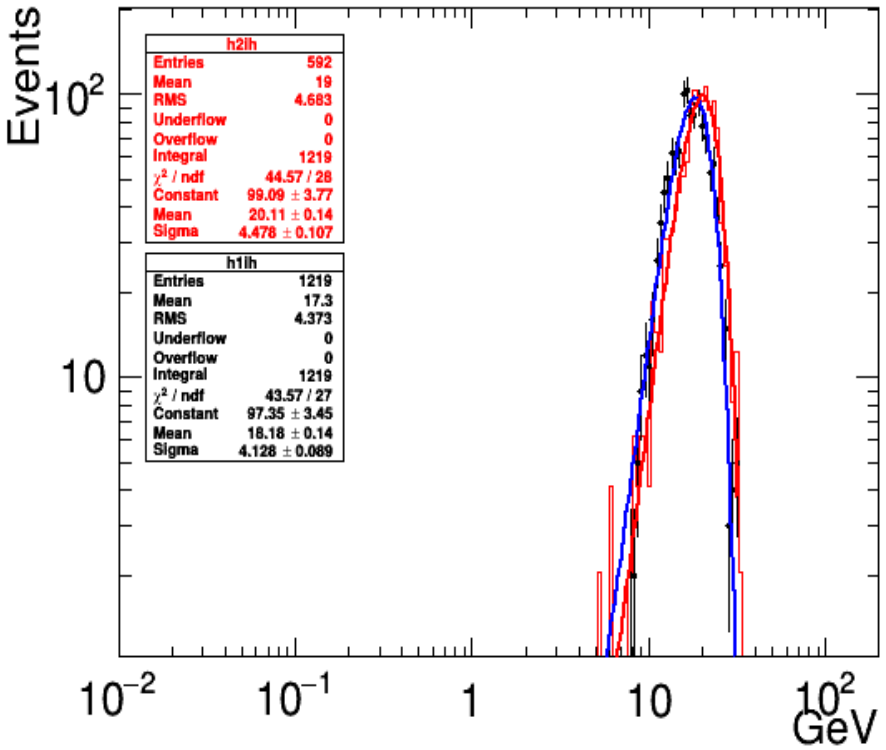


Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.974 +/- 0.015 – Ratio Mean = 0.976 +/- 0.025 (stat+sys)
HE: Ratio Fit = 0.955 +/- 0.015 – Ratio Mean = 0.974 +/- 0.025 (stat+sys)

TASC total energy deposit - 19 GeV/n heliums
10 MIP threshold & 100 MIP threshold
Fluka vs TB data

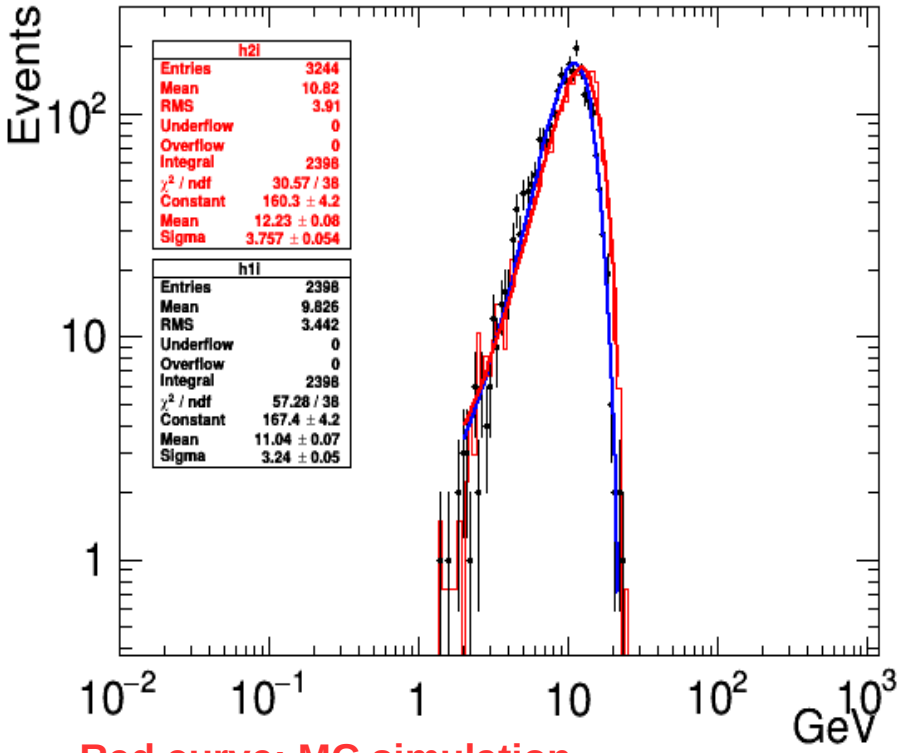


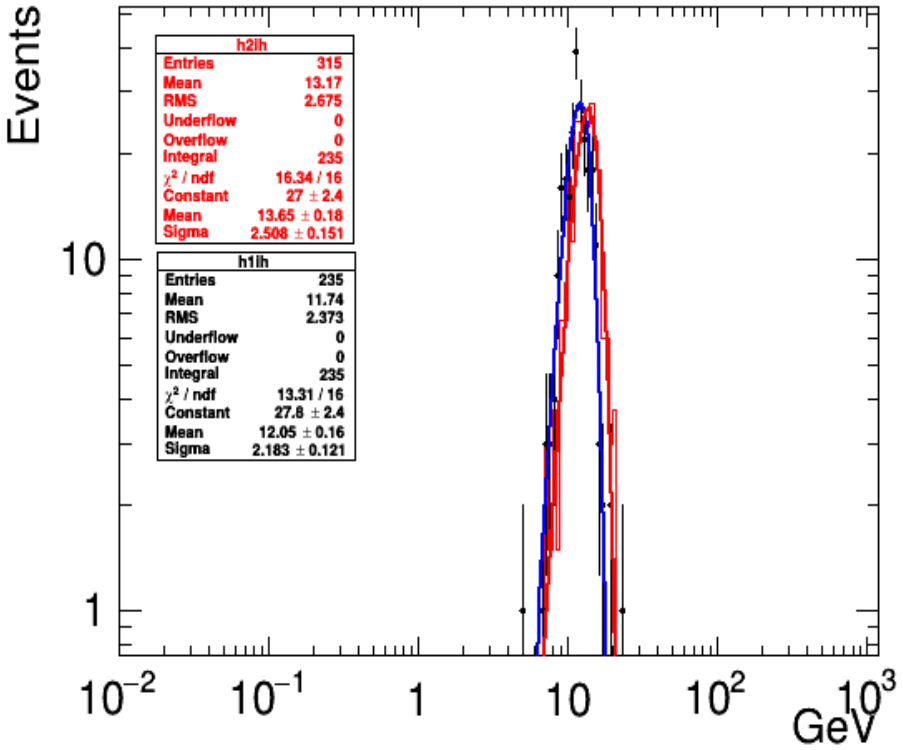


Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.912 +/- 0.025 – Ratio Mean = 0.932 +/- 0.049 (stat+sys)
HE: Ratio Fit = 0.904 +/- 0.050 – Ratio Mean = 0.910 +/- 0.050 (stat+sys)

TASC total energy deposit - 13 GeV/n heliums
10 MIP threshold & 100 MIP threshold
Fluka vs TB data



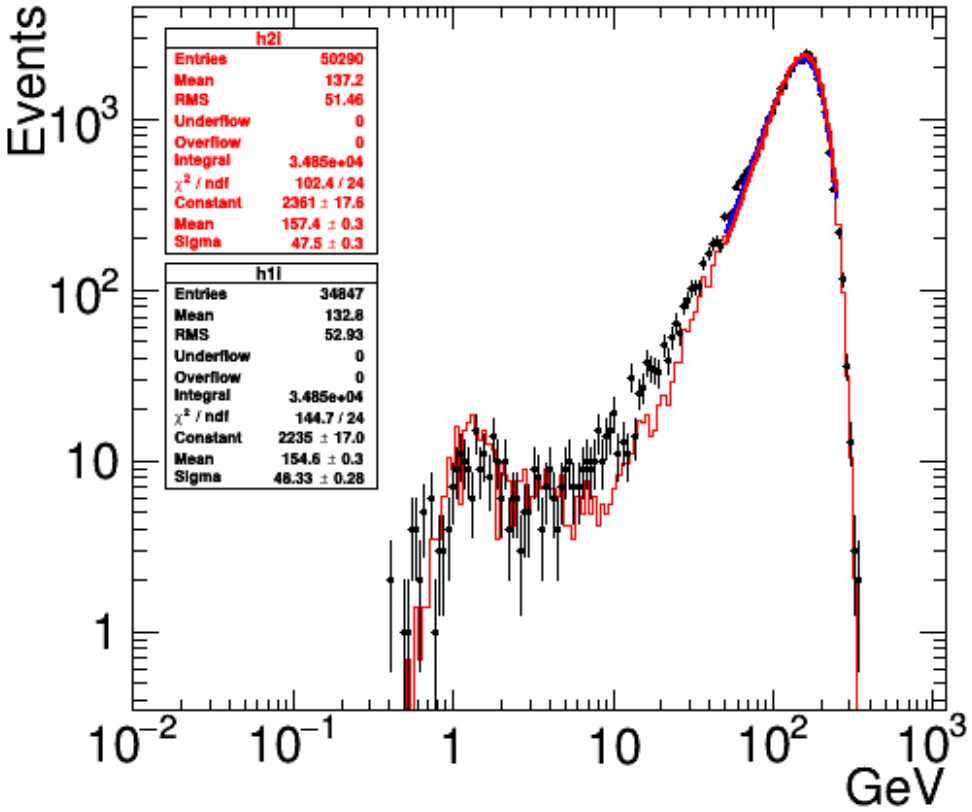


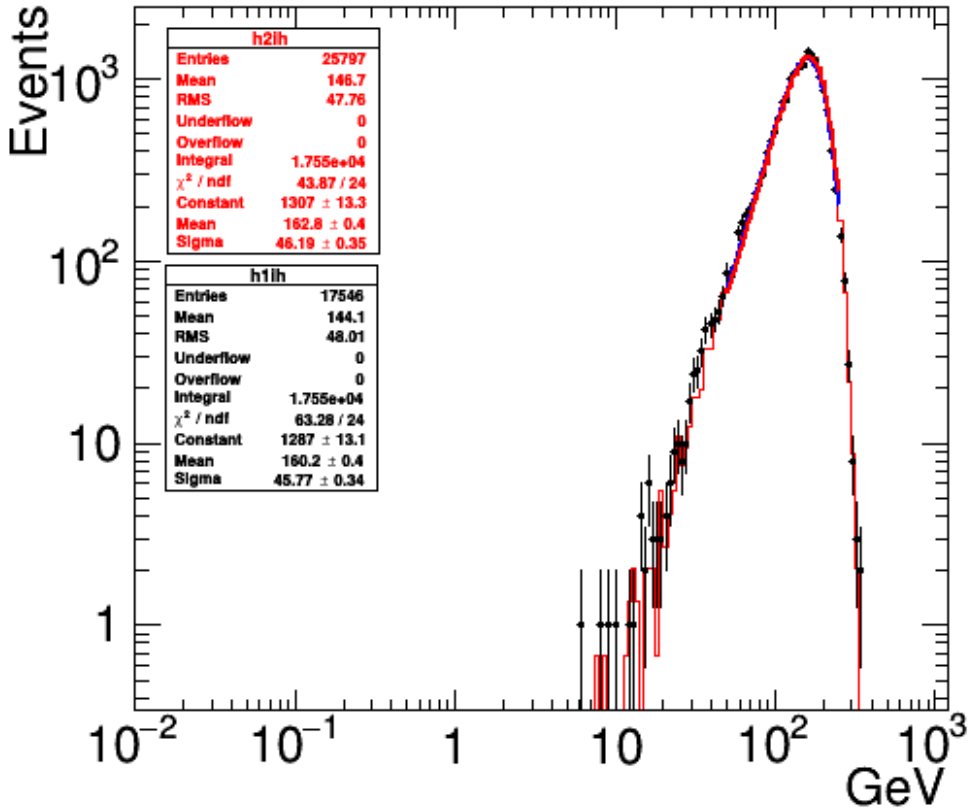
Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.904 +/- 0.040 – Ratio Mean = 0.908 +/- 0.040 (stat+sys)
HE: Ratio Fit = 0.883 +/- 0.080 – Ratio Mean = 0.891 +/- 0.080 (stat+sys)

Study on Energy Scale correction 2.
BT data vs Epics

TASC total energy deposit - 150 GeV/n heliums
10 MIP threshold & 100 MIP threshold
Epics vs TB data

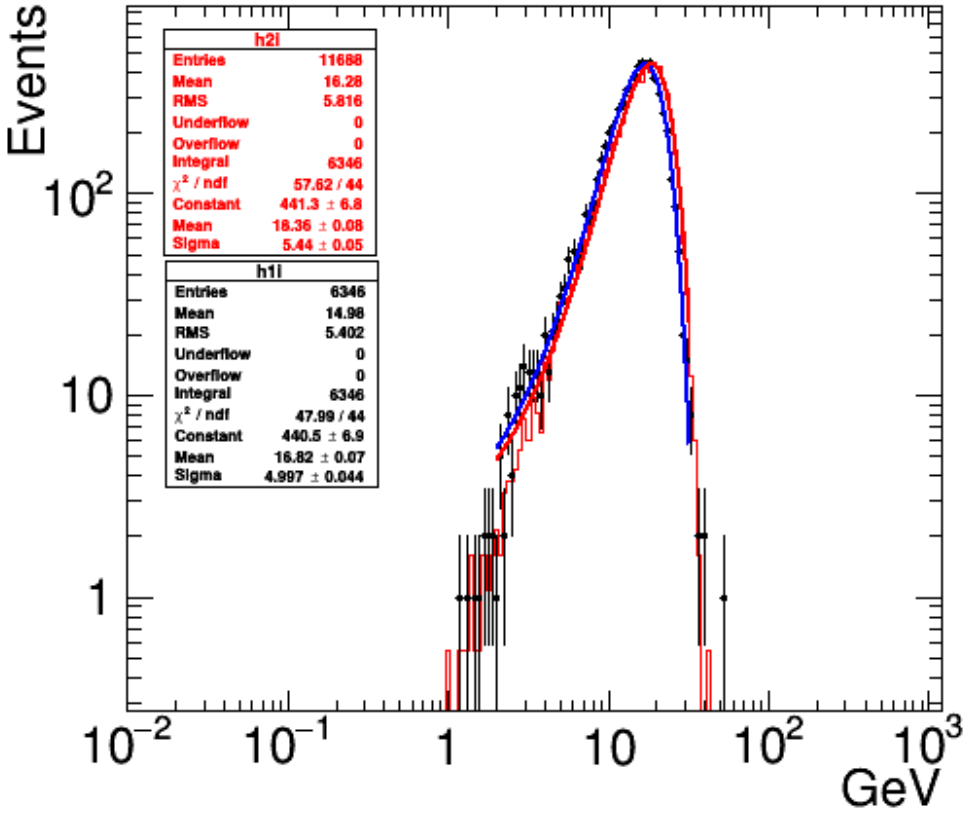


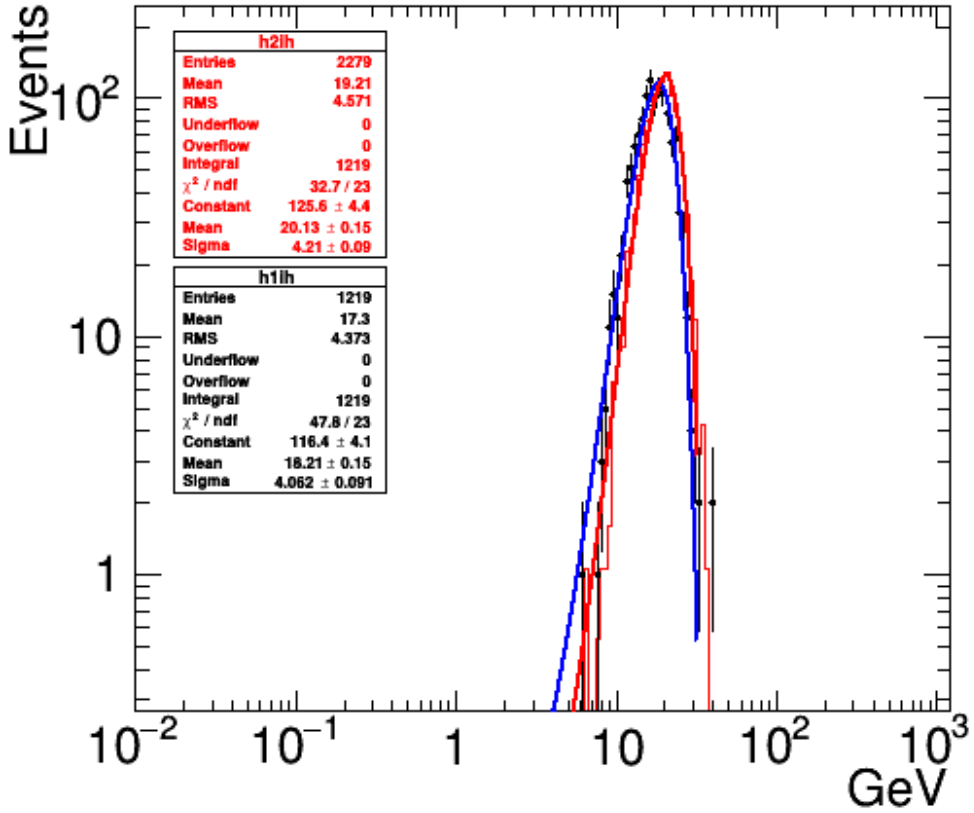


Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.982 +/- 0.020 – Ratio Mean = 0.968 +/- 0.020 (stat+sys)
HE: Ratio Fit = 0.984 +/- 0.020 – Ratio Mean = 0.982 +/- 0.020 (stat+sys)

TASC total energy deposit - 19 GeV/n heliums
10 MIP threshold & 100 MIP threshold
EPICS vs TB data

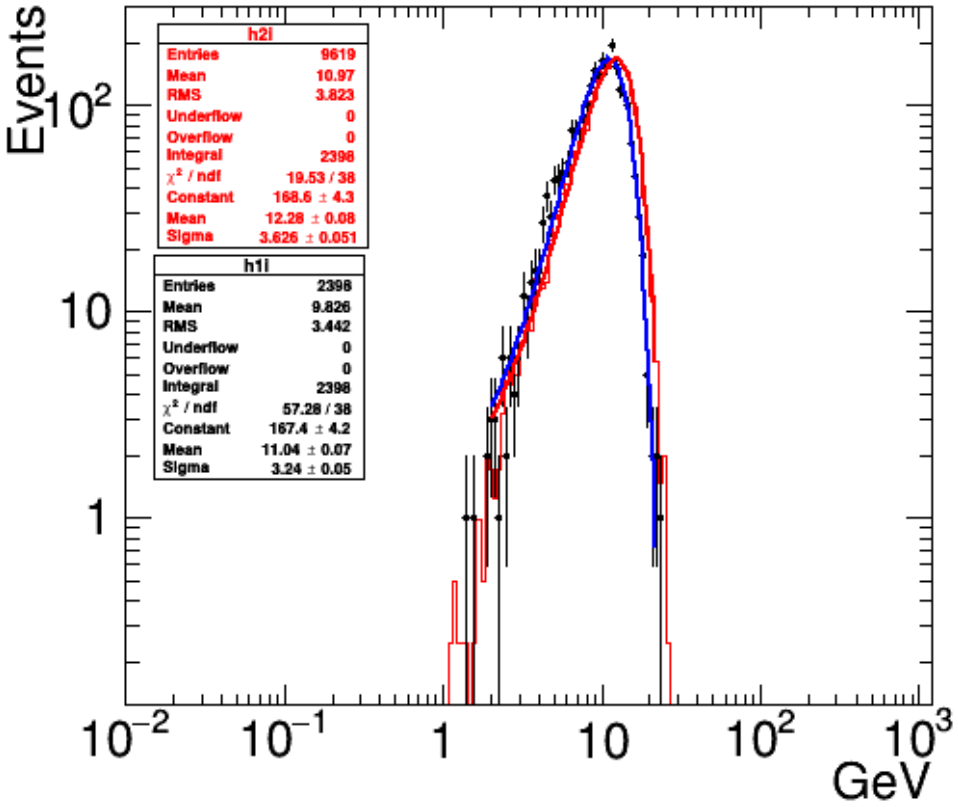


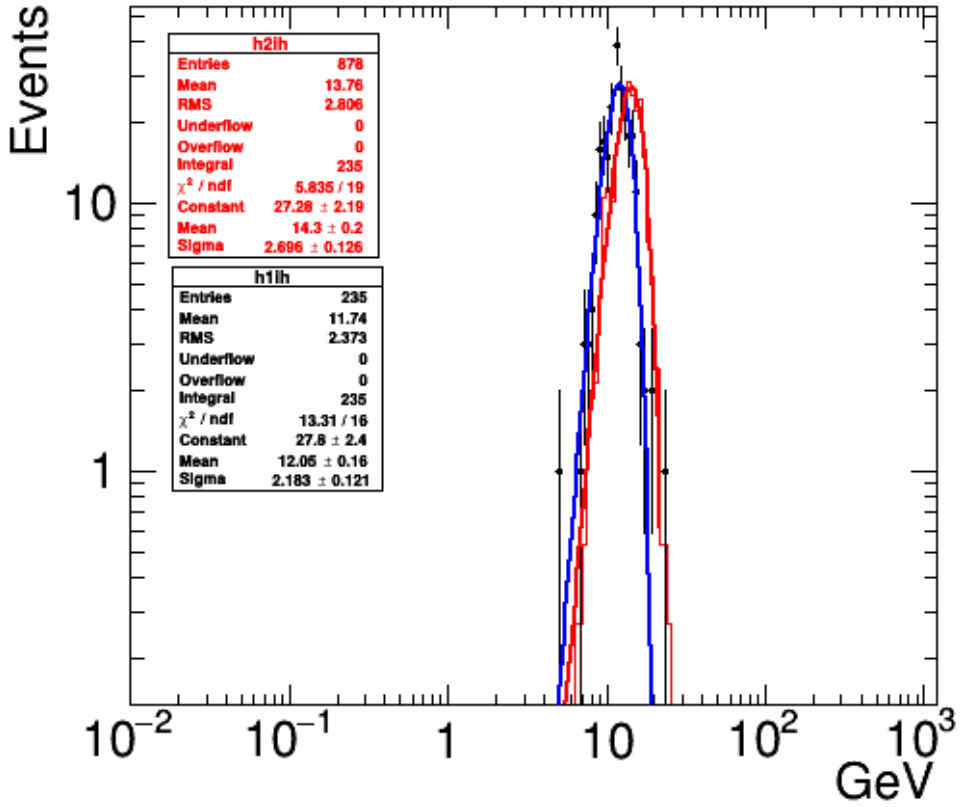


Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.916 +/- 0.025 – Ratio Mean = 0.920 +/- 0.025 (stat+sys)
HE: Ratio Fit = 0.905 +/- 0.050 – Ratio Mean = 0.900 +/- 0.050 (stat+sys)

TASC total energy deposit - 13 GeV/n heliums
10 MIP threshold & 100 MIP threshold
Epics vs TB data

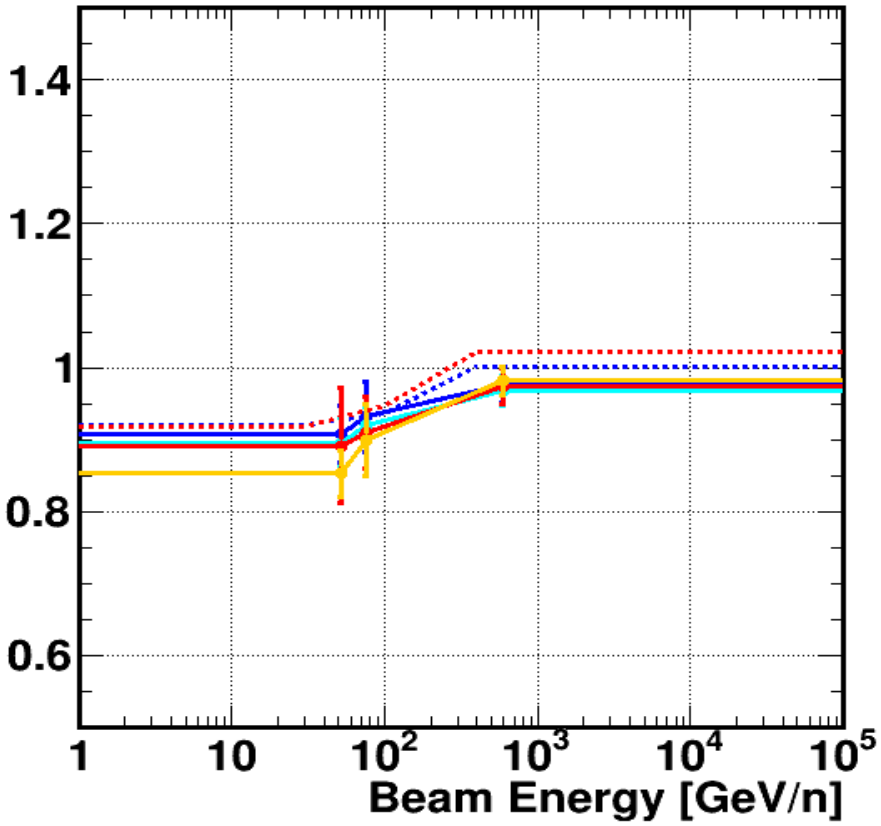




Red curve: MC simulation
Black dots: TB data

LE: Ratio Fit = 0.898 +/- 0.029 – Ratio Mean = 0.896 +/- 0.034 (stat+sys)
HE: Ratio Fit = 0.843 +/- 0.031 – Ratio Mean = 0.853 +/- 0.032 (stat+sys)

Results: TB data vs Fluka/Epics



Red line: HE trigger Fluka
Blue line: LE trigger Fluka
Orange dots: HE trigger Epics
Blue dots: LE trigger Epics
Dashed Red line: HE trigger from JC note
Dashed Blue line: LE trigger from JC note

Fluka – Energy scale correction
(estimated using the ratio of histogram means)

Beam Energy/n	Ratio HE	Ratio HE error	Ratio LE	Ratio LE error
13	0.891	0.080	0.908	0.040
19	0.910	0.050	0.932	0.049
150	0.974	0.025	0.976	0.025

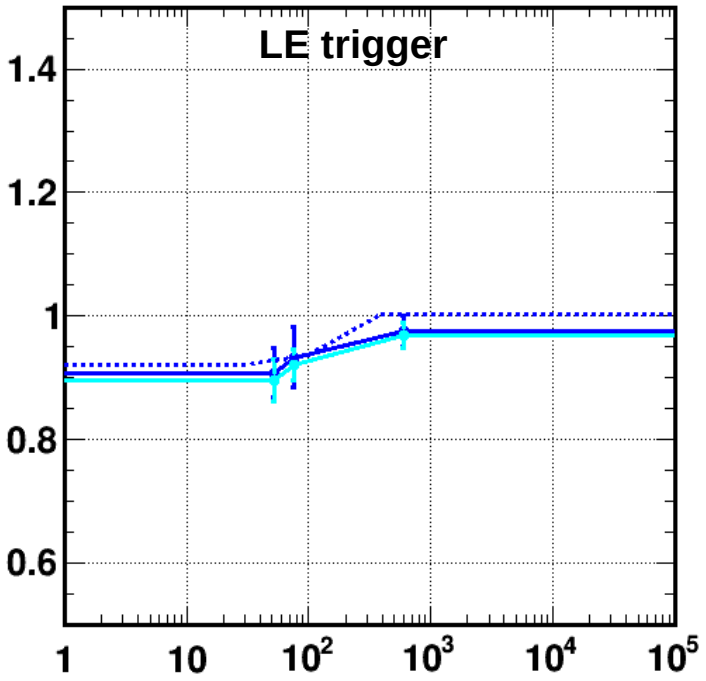
Epics – Energy scale correction
(estimated using the ratio of histogram means)

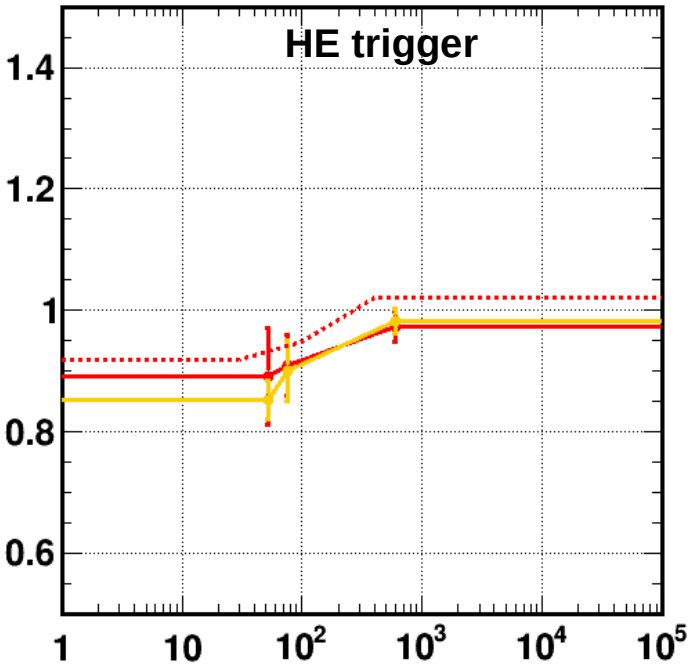
Beam Energy/n	Ratio HE	Ratio HE error	Ratio LE	Ratio LE error
13	0.853	0.032	0.896	0.034
19	0.900	0.050	0.920	0.025
150	0.982	0.020	0.968	0.020

The results (LE & HE trigger cases, both FLUKA & EPICS) seem agree within the errors:

- **above 600 GeV all 4 curves converge to same value**

Results: TB data vs Fluka/Epics (2)





Red dots: HE trigger (Fluka)
Blue dots: LE trigger (Fluka)
Orange dots: HE trigger (Epics)
Blue dots: LE trigger (Epics)

Zoom on the results:

- **LE trigger – FLUKA and EPICS are in good agreement with each other;**
- **HE trigger – FLUKA and EPICS agree within the errors:**
  - **around 13 GeV/n (52 GeV of Total Energy) Epics appears lower than FLUKA**

Conclusions

- **Using the same geometry and material definitions (CALET+IC Beam Tracker), the results for Trigger Efficiency correction (Fluka & Epics) are compatible with no correction scenario.**

- **the results for Energy scale correction (Fluka & Epics) are compatible, within the errors, with the results obtained for protons.**

- **For the future:**
  - **new simulations with a more accurate description of particle beam, with respect to the real one, are necessary (especially for FLUKA) to better understand the systematics on charge cuts;**

  - **a refining of calibration and gain equalization is also necessary to better describe the TASC energy deposit (MIP & Shower regions) in the MC simulations.**